

Status Report for the Small-Tube Lysimeter Facility Fiscal Year 1990

Prepared for the U.S. Department of Energy
Office of Environmental Restoration and
Waste Management



Westinghouse
Hanford Company Richland, Washington

Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

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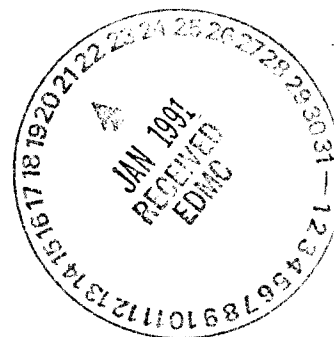
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Status Report for the Small-Tube Lysimeter Facility Fiscal Year 1990

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EXECUTIVE SUMMARY

Westinghouse Hanford Company and Pacific Northwest Laboratory are jointly developing earthen protective barriers for the near surface disposal of radioactive and hazardous waste at the Hanford Site. The proposed barrier design consists of a blanket of fine-textured soil overlying a sequence of layers, varying from sand-to-basalt riprap. The experiments conducted at the Small-Tube Lysimeter Facility were designed to measure the influence of erosion control practices and alternative barrier layering configurations on water movement within the barrier, and extraction of water from the barrier.

This report describes the results of nearly 2 full years of data collection at the Small-Tube Lysimeter Facility. Four concurrent experiments are being performed at this facility, each of these experiments are designed to test different components of the proposed barrier. The experiments are described in the following paragraphs.

Surface Treatment Effects (12 treatments with 5 replications). This experiment is designed to test the effects of various erosion control practices on soil column water storage and evapotranspiration, and includes all combinations of the following main effects:

- Surface treatment (plain soil, gravel admix, gravel mulch)
- Precipitation (ambient and twice average)
- Vegetation (cheatgrass and bare).

Layering Sequence Effects (four treatments, five replications). This experiment is designed to test two different subsurface capillary break structures under twice the long term average precipitation. Treatment include combinations of:

- Layering treatment (pit-run or bimodal gravel versus graded sand)
- Vegetation (cheatgrass and bare).

Surface Sand and Gravel Effects (six treatments, five replications). This experiment is designed to assess the effects of aeolian deposition of sand on a protective barrier under twice average precipitation. The results are compared with the effects of a gravel-mulch, erosion control treatment. Treatments include combinations of the following:

- Surface layer (none, sand, gravel)
- Vegetation (cheatgrass and bare).

Alternative Barriers (three treatments, five replications). Low-permeability, subsurface infiltration barriers are being considered as a built-in redundancy for protection against water infiltration through the

protective barrier. The performance of these alternative barriers is being examined at the Small-Tube Lysimeter Facility. Described in this report are results for clay and chemical grout subsurface barriers. None of the lysimeters are vegetated and all receive twice average precipitation.

The results of this study are summarized in the following paragraphs.

Surface Treatment Effects. All three of the main factors (surface treatment, precipitation, and vegetation) had significant effects on both water storage change and cumulative evapotranspiration. Generally, lysimeters with a gravel mulch surface had significantly greater storage change and significantly less cumulative evapotranspiration than lysimeters with either a soil or gravel admix surface. The presence of vegetation generally increased the evapotranspiration and decreased the amount of storage. Lysimeters that received twice the long-term average precipitation typically had greater evapotranspiration and greater storage than lysimeters that received ambient precipitation. Drainage occurred only in the irrigated gravel mulch treatments.

Layering Sequence Effects. There were no significant storage or evapotranspiration differences between the bimodal and graded subsurface layering treatments. Vegetation tended to increase the evapotranspiration and decrease the total storage change only during the drier portions of the year. No drainage was found in any of the bimodal or graded layer lysimeters.

Surface Sand and Gravel Effects. A sand deposition layer was found to have a similar effect on soil column water balance as a gravel mulch layer. Both types of surface layers significantly decreased the amount of evapotranspiration and increased the amount of storage compared to control lysimeters that have a plain soil surface. Vegetation significantly increased the amount of cumulative evapotranspiration from the sand and gravel covered lysimeters during the second year of measurement. Drainage was detected from both the sand and gravel covered lysimeters, with no significant differences among the treatments.

Alternative Barrier Effects. There were no significant storage or evapotranspiration differences between the clay and grout treatments. However, the grout treatment had significantly higher amounts of evapotranspiration than the control treatments (bimodal and graded capillary breaks) at the early sampling dates. This difference might be attributable to the high water content of the grout slurry used to form this lysimeter layer. The drying of the grout slurry layer may account for the increase in evapotranspiration noted from these lysimeters. None of the clay or grout lysimeters produced detectable drainage.

All barrier configurations with or without plants, and with or without gravel admix, prevented drainage under both ambient and twice average precipitation conditions. This result indicates that the barrier, as currently designed, will prevent water infiltration under the conditions simulated. Barrier configurations that included a surface layer of either

sand or gravel did not prevent drainage. This implies that if a gravel admix surface erodes to form a gravel mulch or if sands are deposited on the barrier surface, then infiltration may be possible. The probabilities of these occurrences should be evaluated.

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LIST OF TERMS

ABS	acrylonitrile-butodiene-styrene
ALE	Hanford Site Arid Lands Ecology Reserve
ANOVA	analysis of variance
ET	evapotranspiration
FLTF	Field Lysimeter Test Facility
FY	fiscal year
HMS	Hanford Meteorological Station
PNL	Pacific Northwest Laboratory
PVC	polyvinyl-chloride
STLF	Small-Tube Lysimeter Facility

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STATUS REPORT FOR THE SMALL-TUBE LYSIMETER TEST FACILITY, FISCAL YEAR 1990

1.0 INTRODUCTION

The Westinghouse Hanford Company (Westinghouse Hanford) and Pacific Northwest Laboratory (PNL) are jointly developing protective barriers for the long-term isolation of low level radioactive and mixed radioactive/hazardous waste at the Hanford Site for the U.S. Department of Energy. Protective barriers have been identified as an integral part of the overall final disposal strategy for low-level defense waste at the Hanford Site (DOE 1987).

Several performance objectives have been developed for a protective barrier: (1) water infiltration to and through the waste should be limited to near-zero amounts, (2) intrusion into the waste by plants, animals, and humans should be minimized, (3) minimal wind and/or water erosion should occur during the functional lifetime of the barrier, and (4) the barrier should be maintenance free and functional for a period up to 10,000 yr. A protective barrier designed to meet these general criteria should isolate the waste, minimize the transport and release of contaminants to the environment, and could be considerable less expensive than other treatment and disposal options (DOE 1987).

The current conceptual design of the Hanford Site protective barrier is a multi-layered earthen structure consisting of a fine soil surface layer overlying a sequence of layers grading downward from sand to basalt riprap. The textural difference between the fine soil and coarser materials functions as a capillary break, which helps prevent water from flowing from the finer material to the coarser material; this allows the fine soil layer to hold more moisture. Water held above the textural interface can then be recycled to the atmosphere through the processes of soil evaporation and plant transpiration. Additional, redundant infiltration barriers of clay, chemical grout, or asphalt also may be included in the design. The basalt rip-rap layer is designed to reduce plant root and animal intrusion into the waste, and also may serve as a deterrent to human intrusion. Erosion control will be accomplished through the placement of gravel on the surface of the fine soil surface either as a mulch, or as an admixture (homogeneous mixture of gravel and soil) in the upper 20 to 30 cm, establishment of a vegetative cover, and control of the barrier surface slope angle. Preliminary wind tunnel investigations indicate that either method would provide adequate protection from wind erosion (Ligotke 1989). The conceptual protective barrier design uses only natural materials that are expected to withstand degradation for at least 10,000 yr.

The Small-Tube Lysimeter Facility (STLF) was designed and constructed to test the effects of different layering sequences, surface erosion control practices, and alternative infiltration barriers on the soil-column water balance of a simulated protective barrier (Waugh and Link 1987, Relyea et al. 1990, Freeman et al. 1989). The conceptual barrier design uses a carefully

graded series of gravel, sand, and fine soil to form a stable capillary break. An alternative structure of the capillary break is fine soil over pitrun gravel. Pitrun gravel has a bimodal particle size distribution (sand and gravel), and is hence termed bimodal gravel in this report. The bimodal gravel design would probably be less expensive to construct and would more closely resemble natural soil structures on the Hanford Site. However, the bimodal design may be less effective in minimizing infiltration; this is currently being tested at the STLF.

The addition of gravel to the barrier surface either as a mulch or as an admix will provide considerable erosion protection compared with a bare soil surface. The surface gravel also may affect infiltration and decrease the amount of soil evaporation, thus increasing the likelihood of water infiltration through the waste. These effects are being examined at the STLF and at the McGee Ranch Admix test plots (Waugh and Link 1987, Waugh 1988). An additional potential problem for a protective barrier is the eolian deposition of sand on top of the fine soil layer. This also would be expected to increase the soil surface infiltration and reduce the amount of soil evaporation. This effect is also being examined at STLF.

The inclusion of a very low permeability sublayer within the protective barrier would function as a redundant infiltration barrier, and would help to protect the underlying waste even under extremely high-intensity storm events. The efficacy of sublayers of clay, chemical grout, and various types of asphalt are being studied at the STLF. Studies involving clay and chemical grout sublayers are described in this report; the asphalt experiments are described separately (Freeman et al. 1989, Freeman and Gee 1989). This report describes the operations and results of nearly 2 yr of data collection at the STLF. Relyea et al. (1990) describe the initial conditions and fill specifications for each of the lysimeters. The results for both fiscal year (FY) 1989 and FY 1990 are analyzed and described in this report.

2.0 MATERIALS AND METHODS

2.1 THE SMALL TUBE LYSIMETER FACILITY

The STLF is located adjacent to the Hanford Meteorological Station (HMS), within the protective Barrier Field Lysimeter Complex. It consists of 105 lysimeters arranged in an array of 21 rows of 5 lysimeters each (Figure 2-1). Eighty of the lysimeters (rows 1 through 16) are used to test the effects of various erosion control practices, sand deposition, and barrier layering sequences on soil column water balance. The remaining 25 lysimeters (rows 17 through 21) are used to test alternative infiltration barriers (clay, chemical grout, asphalt) that have been proposed as impermeable components of a protective barrier system (Freeman et al. 1989).

Each lysimeter consists of a 169 cm long, 30.4 cm internal diameter acrylonitrile-butadiene-styrene (ABS) well casing placed inside a 175-cm-long, 39-cm-dia polyvinyl-chloride (PVC) sleeve. The tops of the sleeves and lysimeter tubes are placed approximately 2.5 cm abovegrade. A rubber insulating collar (36-cm-bicycle inner-tube, painted white) is placed at the upper end of each lysimeter tube in order to minimize heat transfer between the atmosphere and the airspace between the sleeve and lysimeter tube. Each lysimeter tube is fitted with a recessed cap at the bottom and an aluminum lifting collar at the top. The aluminum collar serves both as a rigging attachment point during weighing and as a coupling interface for an acrylic plant gas exchange chamber that is used for separate controlled experiments on photosynthesis and evapotranspiration (ET) (Waugh and Link 1987, Link and Waugh 1989, Link et al. 1990).

The sealed tube serves as a combined weighing and drainage lysimeter. Drainage is measured monthly by collecting water from a clear, flexible polymer tube that is fitted to a threaded drain hole at the low end of the end cap. Changes in water storage are estimated as the monthly weight change, which is measured by suspending the lysimeters from a load cell attached to a gantry crane.

The lysimeters were each filled by hand with layers of gravel, sand, silt loam soil, pit-run gravel, and impermeable barrier material. The exact materials and layering sequences for each tube depended on the assigned treatment combination for that lysimeter (Figure 2-2). The treatment combinations are described in Section 2.2, and complete descriptions of the lift thicknesses, weights, moisture contents and initial conditions for each lysimeter can be found in Relyea et al. (1990). Construction and filling were completed in mid-September 1988. A section of black-steel grating (1 by 2 m) is placed at the soil surface between the rows of lysimeters. These grating sections allow workers to move about the facility with minimal disturbance to the lysimeters.

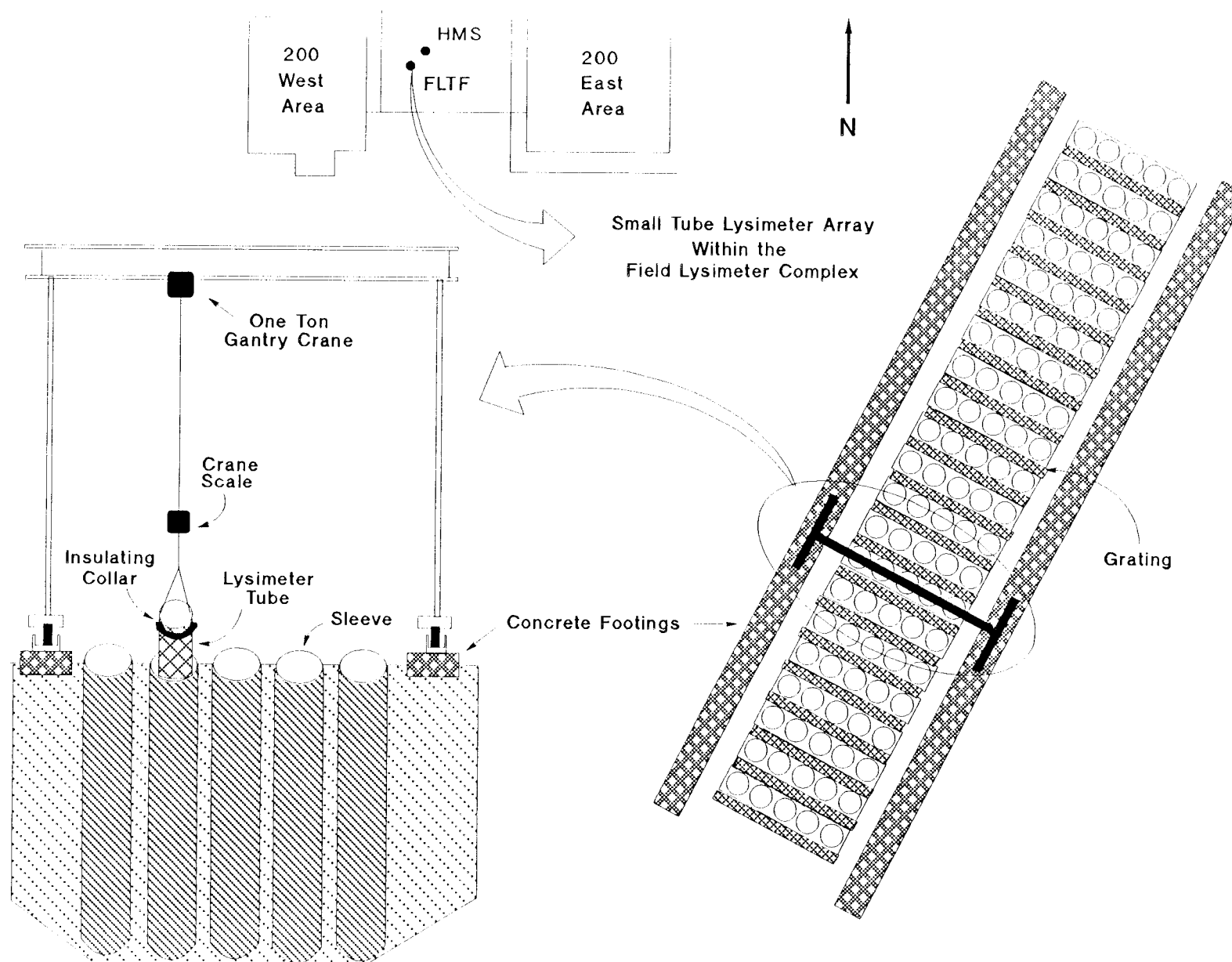


Figure 2-1. Illustration of the Small-Tube Lysimeter Facility.

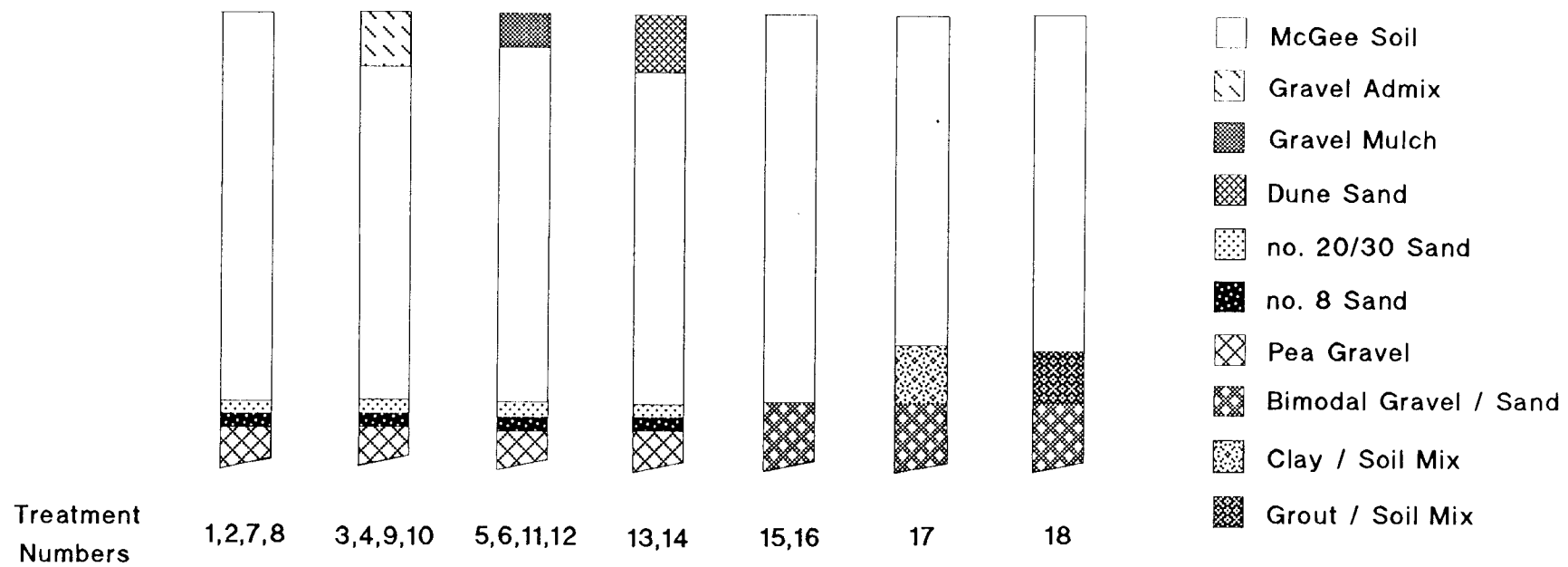


Figure 2-2. Layering Sequences of Small-Tube Lysimeter Facility Treatment Lysimeters.

2.2 DESCRIPTION OF EXPERIMENTS

The experiments at SLTF represent an expansion of the studies conducted at the Field Lysimeter Test Facility (FTLF) (Kirkham et al. 1987). Several of the treatment combinations are in common with the treatments included in the FTLF design, and some match the conditions in previous UNSAT-H simulations of unsaturated soil water movement (Fayer et al. 1985) performed in support of the Hanford Site protective barrier program. The data acquired at SLTF will supplement the FTLF data for validation of the UNSAT-H computer code (Fayer 1990). The primary advantage of performing experiments at SLTF is the ability to greatly increase both the number of treatment combinations and the number of replicates of each treatment, thus improving the statistical power and confidence levels associated with the analysis of the resultant data (Waugh and Link 1987).

The studies conducted at SLTF are primarily comparative experiments devised to measure the influence on water storage, ET, and drainage of the following factors:

- Surface gravel admix and gravel mulch
- Sand deposition
- Twice the long-term average precipitation
- Vegetation
- Structural sequence of the capillary break
- Impermeable alternative infiltration barriers.

One or more of these factors are included in the treatment combination assigned to each lysimeter. These treatment combinations are summarized in Table 2-1. Treatment descriptions and initial results of the asphalt barrier tests are provided in Freeman et al. (1989) and Freeman and Gee (1989).

The inclusion of all six of the factors (previously listed) in one experimental design would require a facility at least twice as large as the present SLTF, and would result in several impractical treatment combinations. Therefore, four interconnected, but separate experiments (statistical models), are performed simultaneously to analyze the effects of the six factors of interest. A complete statistical description of these models is provided in Relyea et al. (1990). The experimental designs are briefly summarized in the following paragraphs.

Experiment 1. The first experiment is a 3 by 2 by 2 factorial analysis of variance (ANOVA) designed to test the effects of erosion control practices. It includes three different surface treatments (plain soil, 30% gravel admix, and surface gravel mulch), two levels of precipitation (ambient and two times the long-term average), and the presence or absence of vegetation. There are

Table 2-1. Treatment Structure for Experiments
at Small-Tube Lysimeter Facility.

Treatment combinations	Barrier layering		Vegetation		Surface treatments			Precipitation	
	Graded	Bimodal	Bare	Cheatgrass	Admix gravel	Surface gravel	Dune sand	Ambient	Twice average
1	X	-	X	-	-	-	-	X	-
2	X	-	X	-	-	-	-	-	X
3	X	-	X	-	X	-	-	X	-
4	X	-	X	-	X	-	-	-	X
5	X	-	X	-	-	X	-	X	-
6	X	-	X	-	-	X	-	-	X
7	X	-	-	X	-	-	-	X	-
8	X	-	-	X	-	-	-	-	X
9	X	-	-	X	X	-	-	X	-
10	X	-	-	X	X	-	-	-	X
11	X	-	-	X	-	X	-	X	-
12	X	-	-	X	-	X	-	-	X
13	X	-	X	-	-	-	X	-	X
14	X	-	-	X	-	-	X	-	X
15	-	X	X	-	-	-	-	-	X
16	-	X	-	X	-	-	-	-	X
17	-	X	X	-	-	-	-	-	X
18	-	X	X	-	-	-	-	-	X

a total of 12 treatment combinations (treatments 1 through 12), with five replicates of each combination. All of the lysimeters in this experiment have a graded capillary break structure.

Experiment 2. This experiment is a 2 by 2 factorial analysis of variance designed to test the effects of different capillary break layering sequences. It includes two different capillary break structures (graded sand versus the bimodal or soil over pit-run gravel/sand structure), and the presence or absence of vegetation. This experiment includes four treatment combinations (treatments 2, 8, 15, and 16) with five replicates of each treatment.

Experiment 3. The third experiment is a 2 by 2 factorial analysis of variance designed to test the effects of a sand deposition layer and vegetation on soil column water balance. It includes two sand deposition treatments (pure soil and 20-cm surface sand layer) and two levels of vegetation (none and cheatgrass). This experiment includes four treatment combinations (treatments 2, 8, 13, and 14) with five replicates of each treatment combination. Each of these lysimeters has the graded sand capillary break. All of the lysimeters in experiments 2 and 3 receive the two times precipitation treatment.

Experiment 4. The fourth experiment uses a one way analysis of variance to compare the effects of a clay subsurface layer (treatment 17), a chemical grout layer (treatment 18), and the designated control treatment (bimodal capillary break - treatment 15), using five replicates of each treatment. We included an additional control treatment (graded subsurface capillary break) in some of the analyses. All of the lysimeters in this experiment receive the two times the precipitation treatment and none are vegetated.

The 80 lysimeters used in experiments 1 through 3 are arranged randomly throughout rows 1 through 16 of the SLTF array (Figure 2-3). The five lysimeters used for testing the clay layer are in row 17, and the five used for chemical grout are in row 18. Rows 19 through 21 are being used for a separate evaluation of asphalt subsurface layers (Freeman et al. 1989) and are not included in the main statistical design.

2.3 SUPPLEMENTAL APPLIED IRRIGATION

Two precipitation treatments are included in the STLF experiments. The ambient treatment lysimeters receive only natural precipitation, which is recorded at the HMS. The two times (twice average) treatment receives natural precipitation plus enough irrigation to bring the total water input twice the long-term average precipitation. Irrigation is applied over a period of 1 to 4 hours within 2 to 3 weeks following the end of each month in which rainfall is less than twice the long-term average. Table 2-2 shows the monthly average precipitation, the recorded precipitation, and the amounts of irrigation applied during each month of the study. In April 1989, some of the ambient tubes were inadvertently irrigated, so the same amount of water (2.49 cm) was subsequently added to all of the ambient tubes to preserve the statistical models previously described.

**SURFACE
TREATMENT
AND
LAYERING
SEQUENCE
EXPERIMENTS**

**ALTERNATE
BARRIER
EXPERIMENTS**

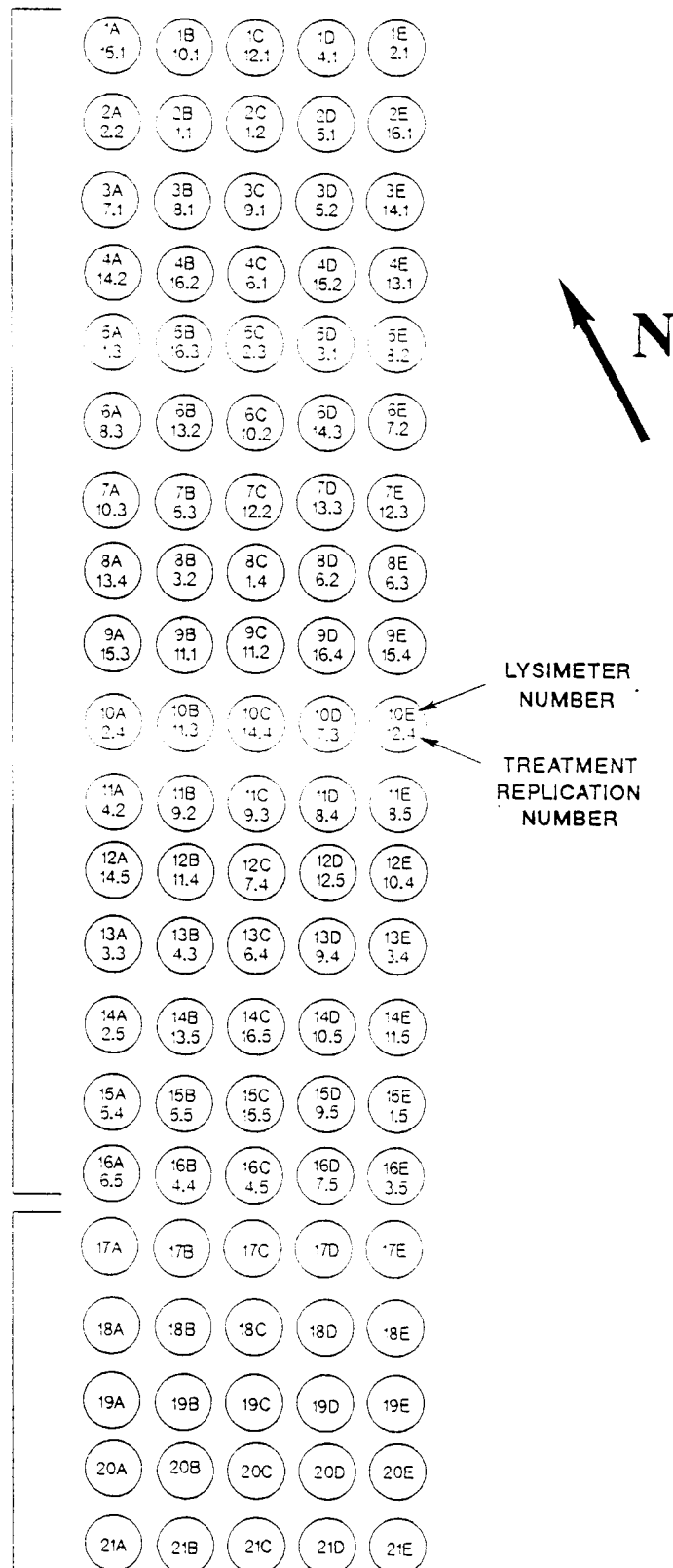


Figure 2-3. Random Assignment of Treatment Combinations.

Table 2-2. Precipitation and Irrigation Amounts Applied at Small-Tube Lysimeter Facility (in centimeters).

Month	Monthly HMS average rainfall	Cumulative monthly average	Cumulative twice average monthly average	HMS recorded precipitation	Cumulative recorded precipitation	Irrigation applied	Cumulative irrigation applied	Sum irrigation + precipitation	Cumulative irrigation + precipitation	Cumulative in ambient tubes
Oct-88	1.42	1.42	2.84	0.03	0.03	0.00	0.00	0.03	0.03	0.03
Nov-88	2.16	3.58	7.16	2.08	2.11	0.00	0.00	2.08	2.11	2.11
Dec-88	2.26	5.84	11.68	1.02	3.12	0.00	0.00	1.02	3.12	3.12
Jan-89	2.34	8.18	16.36	0.53	3.66	0.00	0.00	0.53	3.66	3.66
Feb-89	1.52	9.70	19.40	4.24	7.90	3.50	3.50	7.75	11.40	7.90
Mar-89	0.94	10.64	21.28	3.96	11.86	2.94	6.45	6.91	18.31	11.86
Apr-89	0.99	11.63	23.26	2.13	14.00	2.97	9.42	5.10	23.41	16.48
May-89	1.22	12.85	25.70	1.50	15.49	0.00	9.42	1.50	24.91	17.98
Jun-89	1.37	14.22	28.44	0.03	15.52	0.79	10.21	0.81	25.73	18.01
Jul-89	0.38	14.60	29.20	0.03	15.54	2.71	12.92	2.74	28.47	18.03
Aug-89	0.61	15.21	30.42	0.66	16.21	0.73	13.66	1.39	29.86	18.69
Sep-89	0.79	16.00	32.00	0.05	16.26	0.56	14.21	0.61	30.47	18.74
Oct-89	1.42	17.42	34.84	1.07	17.32	1.53	15.74	2.60	33.07	19.81
Nov-89	2.16	19.58	39.16	2.64	19.96	1.77	17.52	4.41	37.48	22.45
Dec-89	2.26	21.84	43.68	0.74	20.70	1.68	19.20	2.42	39.90	23.19
Jan-90	2.34	24.18	48.36	1.96	22.66	3.78	22.98	5.74	45.64	25.14
Feb-90	1.52	25.70	51.40	0.23	22.89	2.72	25.70	2.95	48.59	25.37
Mar-90	0.94	26.64	53.28	0.25	23.14	2.81	28.51	3.07	51.65	25.63
Apr-90	0.99	27.63	55.26	1.02	24.16	1.63	30.14	2.64	54.30	26.64
May-90	1.22	28.85	57.70	2.18	26.34	0.96	31.10	3.15	57.44	28.83
Jun-90	1.37	30.22	60.44	0.91	27.25	0.26	31.36	1.17	58.61	29.74
Jul-90	0.38	30.60	61.20	0.36	27.61	1.83	33.19	2.18	60.80	30.10

2.4 LYSIMETER PLANTINGS

The 40 lysimeters receiving a vegetated surface treatment (treatments 7 through 12, 14, and 16) were planted to cheatgrass (*Bromus tectorum*) in early October 1989. The seed used was collected from the Hanford Site Arid Lands Ecology Reserve (ALE) during early June 1989. Seeds were hand-stripped from plants selected to be as free of smut as possible. The seeds were air-dried and maintained at room temperature in paper bags until planting. Before planting, the seeds were divided into 40 aliquots of approximately 1,000 seeds each, and each aliquot was individually bagged. Just before planting, cheatgrass litter was obtained from the ALE reserve to serve as mulch.

The following planting procedures were used. On the lysimeters with a surface of plain soil or gravel admix, the soil crust was broken, the seeds contained in one bag were distributed evenly over the disturbed soil, and the seeds were then packed lightly by hand and mulched with approximately one centimeter of cheatgrass litter. On lysimeters with sand surfaces, the sand was lightly disturbed, then the same procedure was followed. Lysimeters with gravel mulch on the surface were not disturbed before planting. At planting, ambient soil moisture was generally low, because the normal autumn rains had not yet begun. In the surrounding environment, cheatgrass had not yet begun to germinate.

Unfortunately, no biomass or leaf area data was collected during FY 1990. However, visual observations indicated that the amount of plant growth on the lysimeters was considerably less than in the surrounding native stands.

2.5 TEMPERATURE EFFECTS

Questions concerning thermal gradients in and around the lysimeters were raised and addressed during FY 1990. Two basic issues were addressed: (1) the possibility of uneven surface temperatures because of the presence of the black-steel grating placed between the lysimeter rows, and (2) vertical gradients within the annulus between the lysimeter tubes and the sleeves that may create temperature profiles that are not reflective of the natural soil profiles.

2.5.1 Surface Temperatures

Surface temperatures were measured to document the extent to which the black-steel grating, which serves as a walkway above the soil and between lysimeter rows, can modify surface temperatures on the lysimeters. Temperatures were measured with a hand-held radiometer. In addition to the temperature measurements made on the grating and on the soil surface directly below the grating, the surface temperatures of selected treatment lysimeters were measured. All measurements were made on March 29, 1990, under clear-sky conditions in the early afternoon (approximately 12:45 p.m. to 1:30 p.m.).

Because the sun's rays were oblique to the vertically oriented openings in the grating at the time of the temperature measurements, the soil beneath the steel grating was shaded by the grating.

Mean temperatures of the different surfaces are listed in Table 2-3. One-way analysis of variance for the effects of surface showed significant surface-temperature differences ($F=50.95$, $p<0.0001$). Table 2-3 also shows the results of the conservative Scheffe F-test (Snedecor and Cochran 1980) comparing temperatures for the surfaces of the lysimeters, the soil below the steel grating near lysimeter rows 15 and 16, and the grating near lysimeter rows 15 and 16.

Shading by the grating caused the surface of the soil between lysimeter rows to be significantly cooler than any of the lysimeter surfaces or the grating itself, both of which were exposed to direct sunlight. Shading resulted in temperatures approximately 8 °C cooler below the grating compared with the vegetated and bare soil surfaces (Table 2-3). Although additional measurements were not taken, it would be expected that the midday temperature differences would decrease later in the summer as the solar angle increases and the relative amount of shading decreases. In general, the dark-colored surfaces (sand, gravel, and grating) were significantly warmer than the lighter-colored surfaces (soil and admix).

An additional effect that the black grating may have is the formation of a heat island around the STLF. Such a heat island could alter both the surface and surrounding air temperature patterns in a uniform manner. The higher temperatures, as well as the increased air movement across the facility that could be caused by the heat island, would increase the amount of evapotranspiration from the lysimeter surfaces. This can be addressed in the future by using infra-red photography and/or measuring air temperature profiles along a transect across the facility, and in adjacent native areas.

2.5.2 Subsurface Lysimeter Temperatures

Concern that lysimeter soil temperatures may differ from nearby soil temperatures outside the lysimeters prompted an investigation of lysimeter soil-temperature profiles. The ET measured in the lysimeters may not be representative of natural conditions when the temperature in the lysimeter is unlike that in the surrounding soil. Temperature-profile measurements began in October 1989, approximately 1 yr after soil water balance data collection began. The lysimeters are positioned inside parallel-walled sleeves that result in a 3- to 4-cm air gap the length of the lysimeter between the outside lysimeter wall and the inside of the sleeve. Thus, the lysimeter design allows free access of outside air to the bottom of the lysimeter.

Thermocouples were installed in lysimeters 16d and 16e at depths of 1, 10, 50, 100, and 140 cm. Holes were drilled through the lysimeter walls, and thermocouples were pushed into the soil 2 cm past the lysimeter wall. Thermocouples also were installed in the space between the lysimeter and the sleeve casing at depths corresponding to the thermocouples placed inside of the lysimeters. A control hole was dug 1 m outside the lysimeter facility to

Table 2-3. Mean Soil Surface Temperatures (March 29, 1990).

Surface treatment	Mean temperature ^a °C (\pm S.D.)	Treatments with significantly different ^b temperatures
Bare soil (A)	35.0 (2.0)	I,J,K
Bare sand (B)	38.8 (1.2)	C,J,K
Bare admix (C)	32.4 (1.4)	B,D,E,F,G,H,I,J,K
Bare gravel (D)	39.3 (1.3)	B,E,J,K
Vegetated Soil (E)	34.7 (2.3)	D,I,J,K
Vegetated admix (F)	37.7 (2.3)	C,J,K
Vegetated gravel (G)	38.1 (1.1)	C,J,K
Grating row 15 (H)	37.6 (0.8)	C,J,K
Grating row 16 (I)	39.9 (0.7)	A,C,E,J,K
Soil < grating 15 (J)	26.5 (0.9)	A,B,C,D,E,F,G,H,I
Soil < grating 16 (K)	26.2 (1.5)	A,B,C,D,E,F,G,H,I

^aMean of five sample measurements.^bScheffe F-test at $p = 0.05$.

S.D. = Standard deviation.

monitor the temperature profile of the native soil. Thermocouple depths in the control hole correspond to depths of thermocouples in the lysimeters, except that the deepest control depth was 128 cm rather than 140 cm, because rocks prevented deeper installation. Beginning October 27, 1987, hourly temperature readings were collected from all of the thermocouples with a Campbell CR7* micrologger. A Campbell CR7 micrologger was installed October 27, 1989 (to record hourly temperatures in the lysimeters) in the annulus between lysimeters and sleeves, and in the control profile.

The results of the temperature monitoring indicated that lysimeter soil temperature closely paralleled the temperatures in the air gap, and mid-winter temperatures were consistently about 3 °C cooler in the lysimeters than in the control soil at the 100-cm depth (Figure 2-4). These results prompted a decision to insulate the lysimeters.

Several insulation methods were considered but rejected because of the concern that the insulation would absorb water and therefore influence lysimeter weights, making it impossible to accurately determine soil water-balance parameters by weight change alone. Even a closed cell foam was found

*Campbell CR7 is a trademark of Campbell Scientific Instruments, Inc., Logan, Utah.

to absorb considerable amounts of water. It was determined that bicycle inner-tubes of the proper diameter were available and fit snugly over the lysimeters and when inflated would fill the interspace between the lysimeter and the sleeve. Initial trials indicated the inner-tubes are easily installed and removed, are flexible, and perform as an inflatable rubber gasket without absorbing water.

The inner-tube gaskets were installed on the lysimeters in row 16 on March 5, 1990. Figure 2-5 shows temperatures at the 100-cm depth for lysimeters 16d and for the control soil outside the lysimeters before and after the installation of the insulation gaskets. After the inner-tubes were installed the temperatures inside the lysimeters began to track the control soil temperatures more closely than before installation. Short-term fluctuations in temperature were damped, and the lysimeter temperature more closely approached the control soil temperatures. Insulating gaskets were installed on all of the lysimeters in rows 1 - 18 on April 2, 1990.

2.6 DATA MANAGEMENT SYSTEM

The data management system is used to store, retrieve, and analyze data from the small-tube lysimeter experiments. Data acquired routinely for the tube lysimeter studies include the following:

- Monthly rainfall measurements from the HMS
- Volume of irrigation applied
- Monthly lysimeter weights and scale calibration weights
- Soil temperature measurements
- Volume of subsurface drainage from the lysimeters
- Leaf area and biomass measurements.

The data management system consists of five basic components: (1) standardized data collection forms designed to encourage recorders to consistently enter all essential field information, (2) methods for consistent data entry into the computer and for quality control verification of the data, (3) data coding, sorting, and restructuring programs to make the system accessible to analysis and graphics programs, (4) data graphics programs, and (5) data analysis programs. Field data that are subject to rigorous analysis are maintained on a mainframe computer (ZVAX) located in the Sigma V Building at PNL. Supporting data that require only tracking and/or summarizing are kept in standard spreadsheet files on personal computers. All ZVAX programs are written in the SAS* system language for data management and analysis. The data are accessible by modem or direct link for graphics and analysis on the ZVAX and for importing to mini- and micro-computer operation systems.

*SAS is a trademark of the SAS Institute Inc.

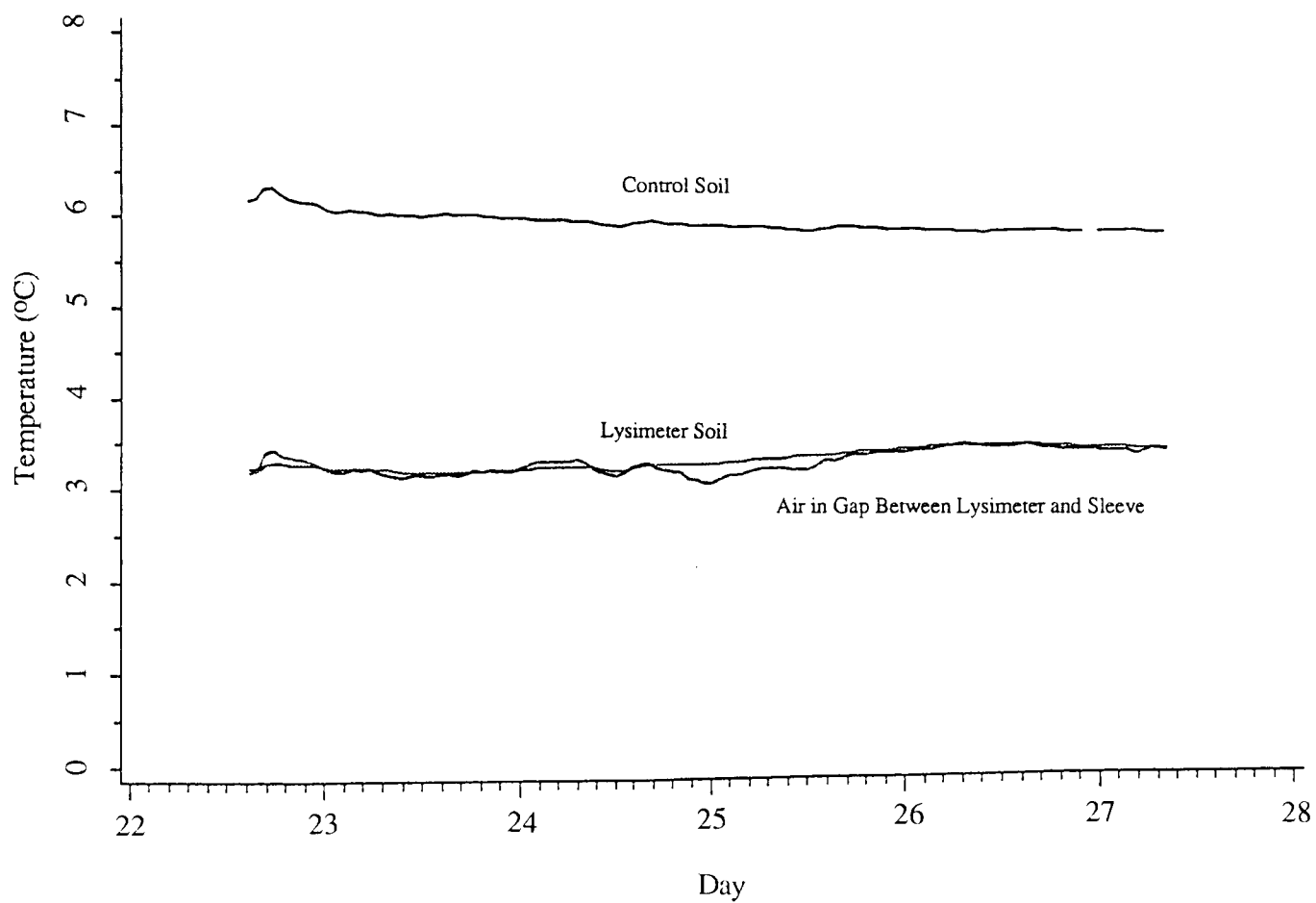


Figure 2-4. Temperatures at 100 cm in Soil in Lysimeter 16e, in the Air Gap Between the Lysimeter and the Surrounding Sleeve, and in Control Soil during December 1989.

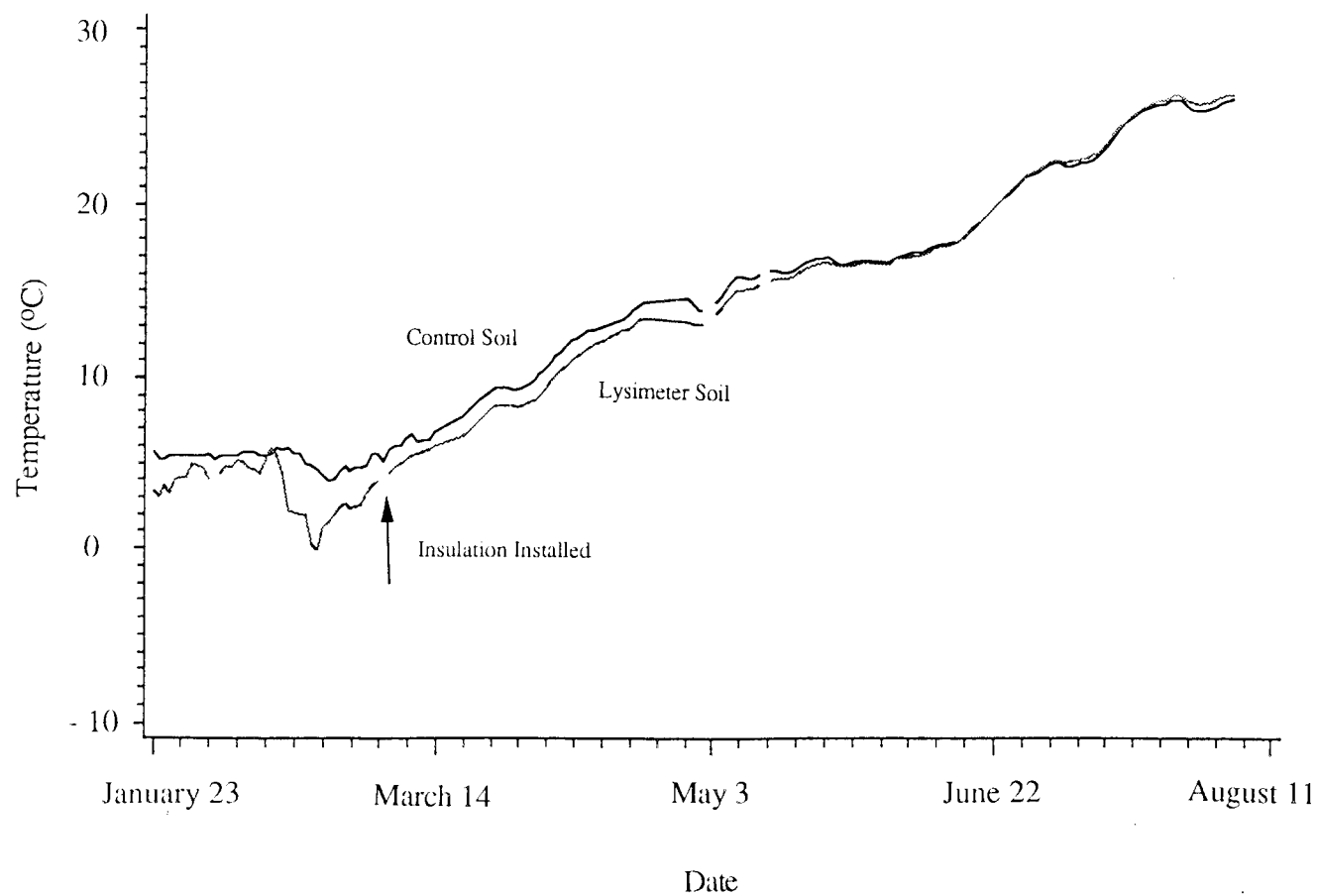


Figure 2-5. Soil Temperatures at a Depth of 100 cm in Lysimeter 16d and in Control Soil during 1990.

The data management structure is shown in Figure 2-6. All field data records are stored in a Quality Assurance (QA) impact level 3 project file in Room 35, the 331 Building, in the 300 Area of the Hanford Site. The lysimeter weight and soil temperature data are transferred to the ZVAX. Lysimeter weight data are entered on separate files for each sampling session. After editing and verifying entries, files are merged into a single file for analysis and graphics. This composite file can be accessed in the following manner:

Directory PNLZ::DISK7:[tule.lys]:tubewt.dat

Files are printed after each entry and then checked by a person other than the one who entered the data. Data entry and data verification personnel record their initials and the date of work in the following QA file:

Directory PNLZ::DISK7:[TULE.QA]:summary.dsc

After raw weight data and drainage are entered into the SAS file, the program assigns to each lysimeter the appropriate treatment number and a replicate number. Lysimeters are coded by (1) whether they receive ambient or twice average precipitation, (2) whether they are vegetated or bare, (3) the surface cover (soil, admix, gravel mulch, sand), and (4) the type of subsurface barrier (graded, bimodal, clay, grout). Sampling times are converted to Julian days and to SAS time to assist in graphing. Data are then transposed by attaching treatment qualifiers so that each data point is uniquely identified.

Standard scale weights, measured at the beginning and end of each monthly sampling session, are entered in a separate file.

Directory PNLZ::DISK7:[TULE.LYS]:caltestB.dat

To remove drift in scale electronics and changes in environmental influences among sampling sessions, the data are standardized using a new calibration factor determined by linear regression coefficients derived from the field calibration (Relyea et al. 1990) for each sampling period.

Several SAS programs were written to process changes in ET for each lysimeter. These programs include inputs such as rainfall and irrigation data, which are updated monthly on a personal computer spreadsheet and transferred to the SAS program. Collectively, the programs (1) convert lysimeter weight changes to changes in ET and storage, (2) sort ET and storage data by treatment, (3) calculate mean and standard deviation statistics for the various treatment combinations, and (4) test for treatment effects and interactions using four separate balanced statistical designs using the ANOVA models described by Relyea et al. (1990) and in Section 2.2.

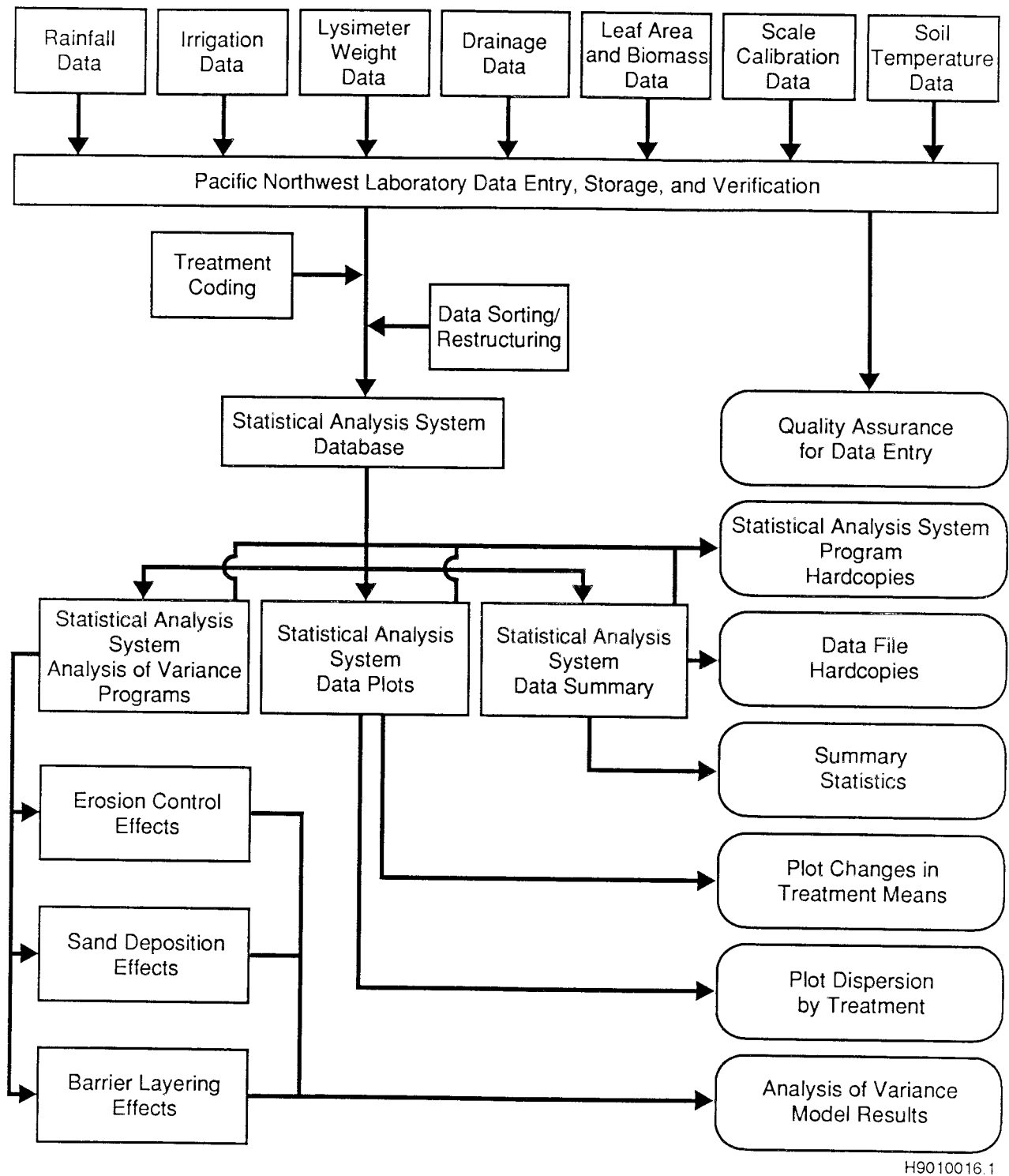


Figure 2-6. Data Analysis Structure of the Small-Tube Lysimeter Facility.

3.0 WATER BALANCE RESULTS

Reported here are the overall trends in water storage and ET, as well as more rigorous statistical analysis of ET and storage for four selected measurement dates (May 1989, October 1989, May 1990, and August 1990). These dates were selected because they represent the beginning of the water year (October 1989 and August 1990) when storage changes are at yearly minima, or at the latter portion of the cheatgrass growth season (May) to accentuate the effects of vegetation. In general, the treatment differences described for these selected dates are representative of the treatment differences present at the other 16 measurement dates. Treatment differences at the selected sampling dates were compared using Duncan's multiple range test (Snedecor and Cochran 1980).

3.1 SURFACE TREATMENTS

The long-term patterns in mean cumulative ET for the different surface treatments are presented in Figures 3-1 and 3-2. The companion long-term patterns in storage change are presented in Figures 3-3 and 3-4. In general, all three of the main factors (surface treatment, vegetation, precipitation) had significant effects on both cumulative ET and storage change. The lysimeters with a gravel mulch surface had the least amount of ET and the greatest change in storage. All of the gravel mulch treatments, except the vegetated/ambient precipitation treatment had an increase in the amount of water stored in the lysimeters after nearly 2 yr of measurements. The lysimeters with soil and admix surfaces behaved very similarly throughout the measurement period, and were affected by both vegetation and precipitation. The only lysimeters that produced drainage were those that had a gravel mulch surface and received twice average precipitation.

On the May 1989 measurement date, all of the gravel mulch treatments had significantly ($p < 0.05$) less cumulative ET than any of the soil or admix surface treatment combinations (Figure 3-5). Neither vegetation nor the amount of precipitation or irrigation had a significant affect on ET when a gravel mulch surface was present. By this measurement date, the gravel mulch treatment lysimeters had evapotranspired 5 to 7 cm of water, whereas the soil and admix lysimeters had evapotranspired 15 to 20 cm of water. The amount of precipitation had a small affect on the amount of ET in the soil and admix treatment lysimeters (Figure 3-5), but the twice average precipitation treatments were significantly greater than only two of the ambient precipitation treatments (bare/admix and veg/soil). Vegetation had no real affect on ET at this measurement date.

All of the treatment combinations had either near zero or positive storage change (gained water) by the May 1989 measurement date (Figure 3-6). All of the gravel mulch treatment combinations had significantly greater storage than the soil or admix treatment combinations, and stored two to four times the amount of water. The amount of precipitation significantly affected the storage in the gravel mulch treatments, and had a slight, but for the most

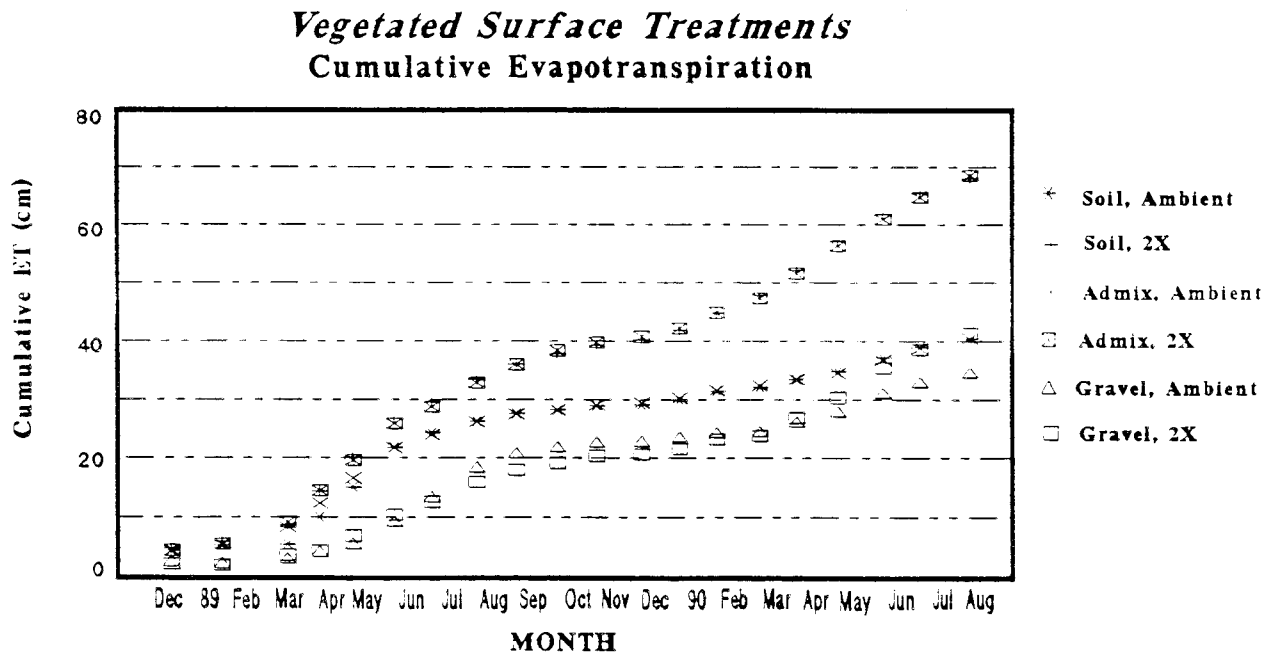


Figure 3-1. Vegetated Surface Treatments (Cumulative Evapotranspiration).

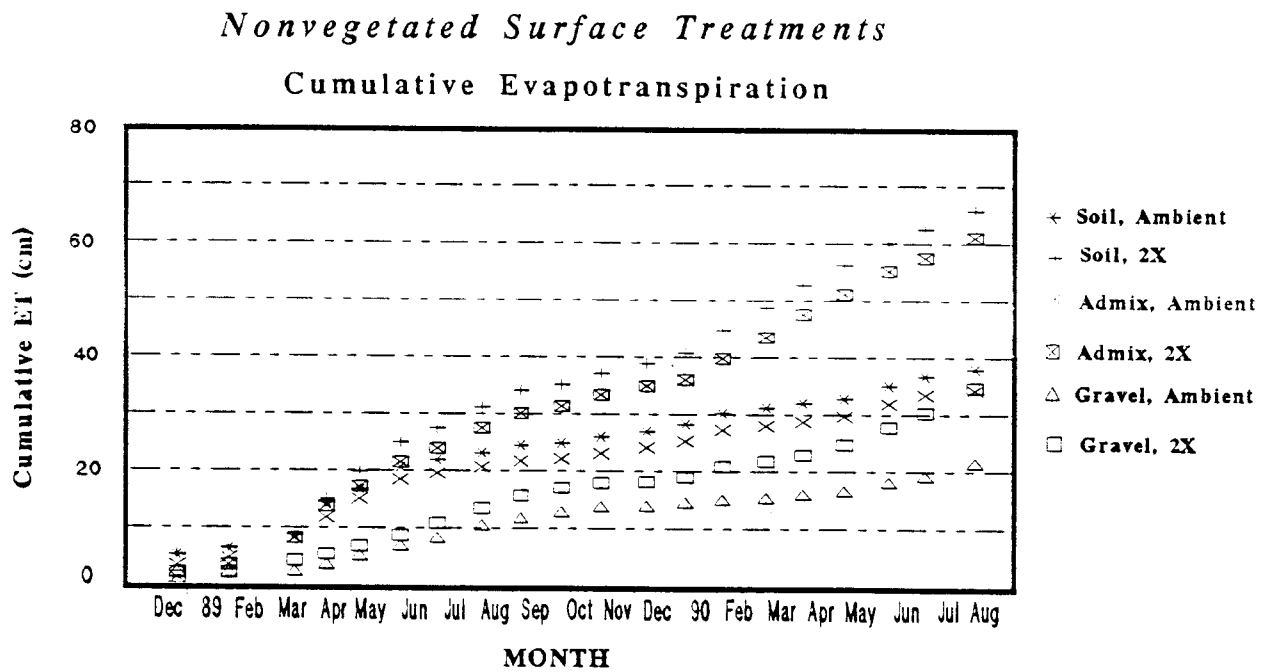


Figure 3-2. Vegetated Surface Treatments (Storage Change).

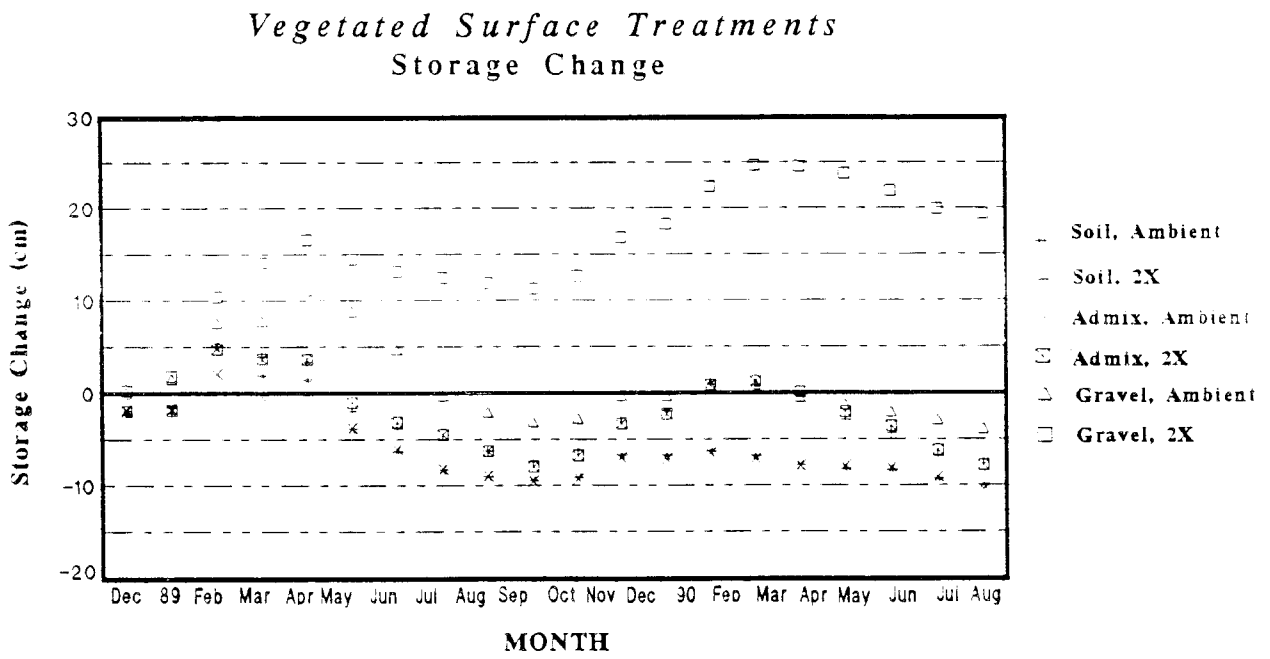


Figure 3-3. Cumulative Storage Change for Vegetated Surface Treatments.

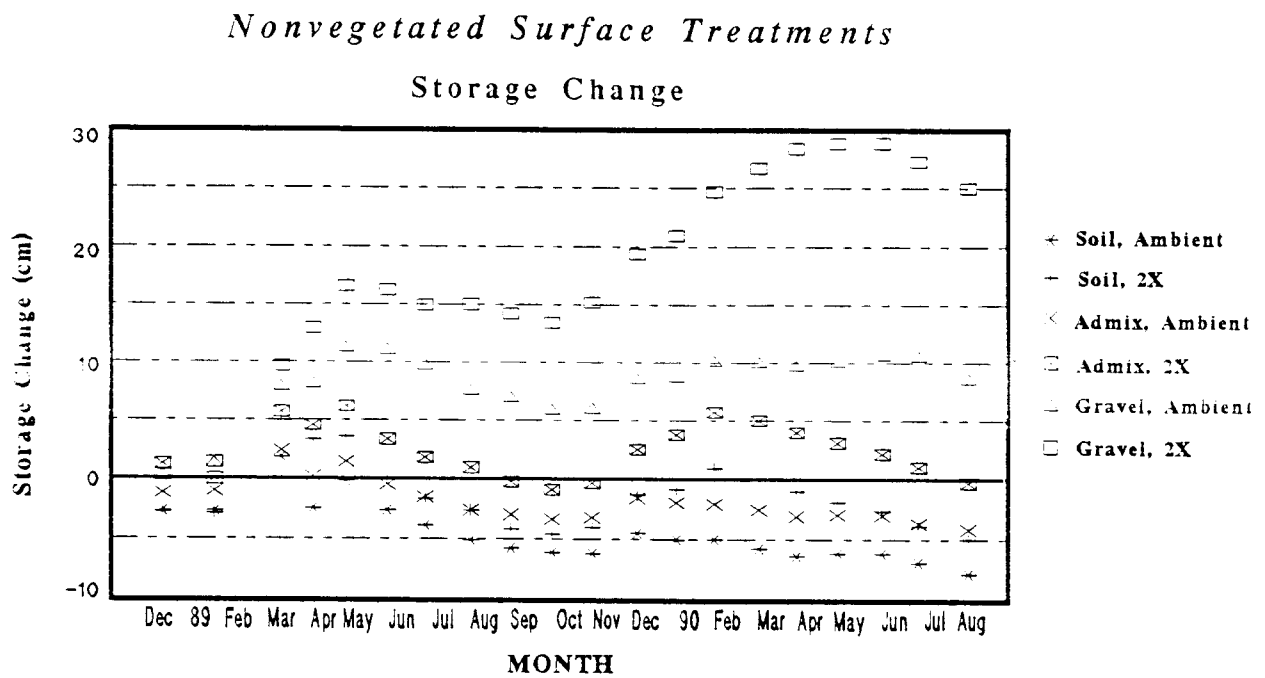
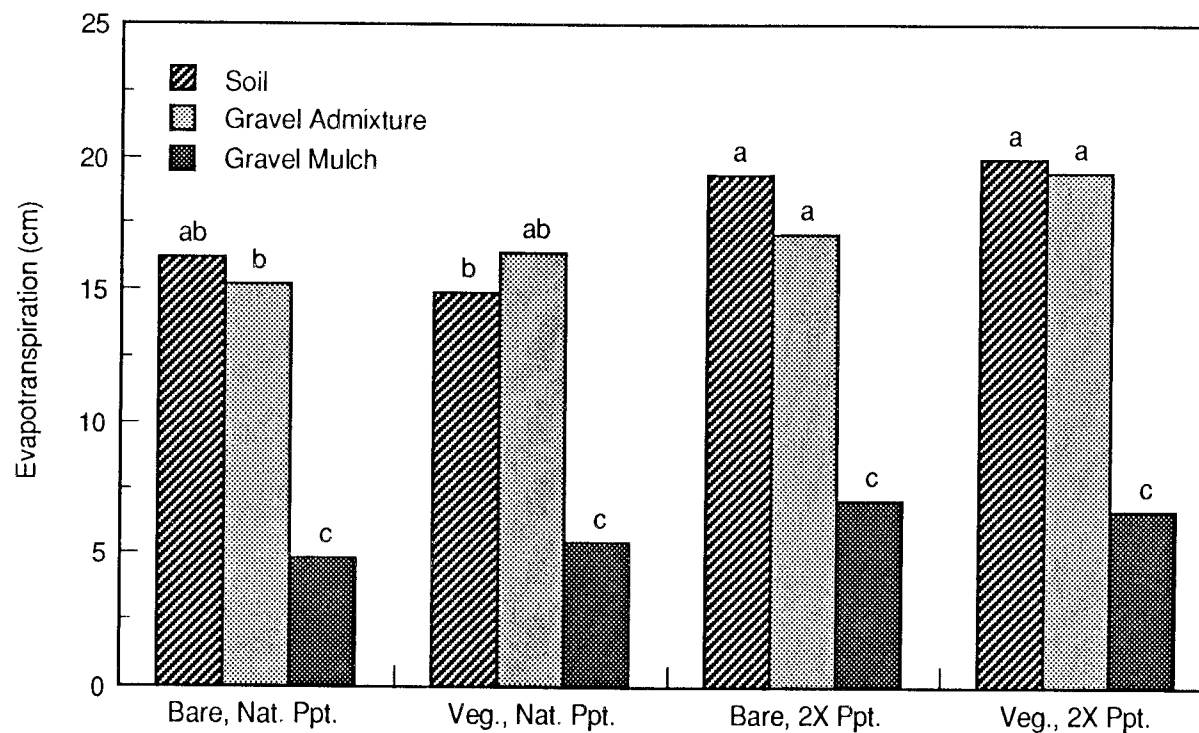


Figure 3-4. Cumulative Storage Change for Nonvegetated Surface Treatments.

Total Evapotranspiration from August 1988 - May 1989



Bars labeled with the same letters are not significantly different.

Nat. Ppt. = natural precipitation

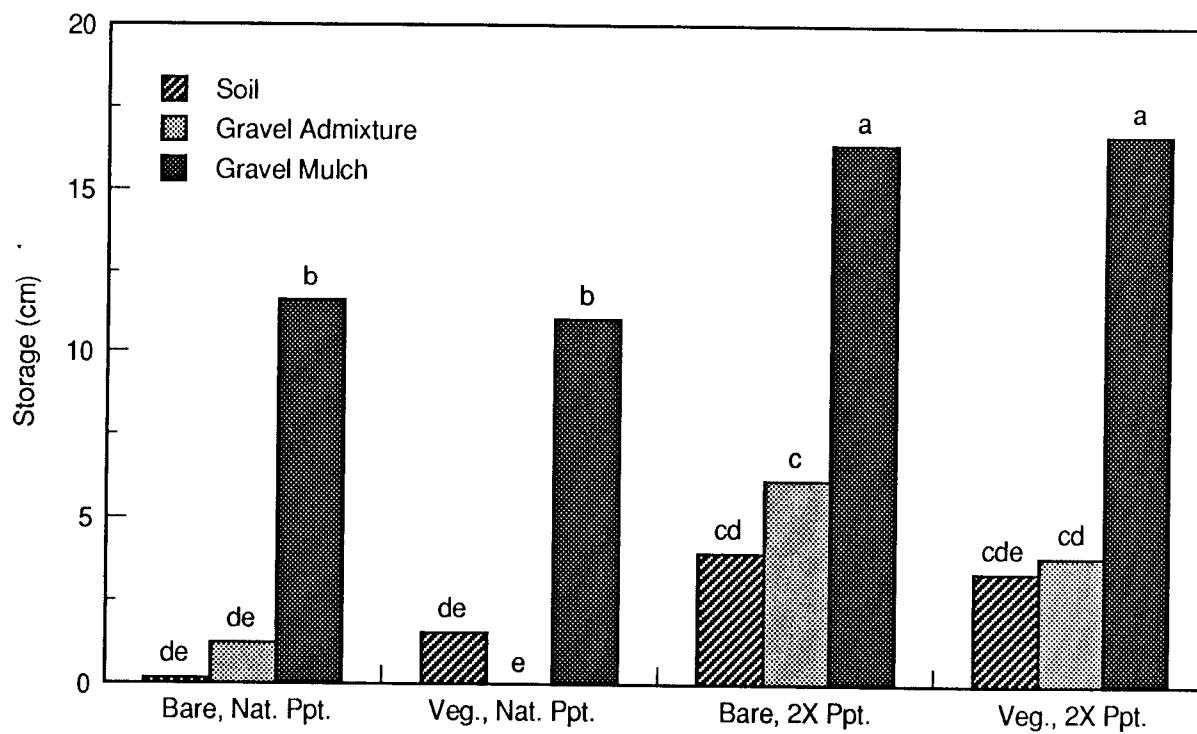
Veg. = vegetated

2X Ppt. = twice average precipitation

H9010024.11

Figure 3-5. Cumulative Evapotranspiration for Three Surface Covers (May 1989).

Storage (cm) from August 1988 - May 1989



Bars labeled with the same letters are not significantly different.

Nat. Ppt. = natural precipitation

Veg. = vegetated

2X Ppt. = twice average precipitation

H9010024.7

Figure 3-6. Storage Change for Three Surface Covers (May 1989).

part nonsignificant, affect on the soil and admix treatments. The presence of vegetation did not significantly affect the storage change for any of the surface treatment combinations.

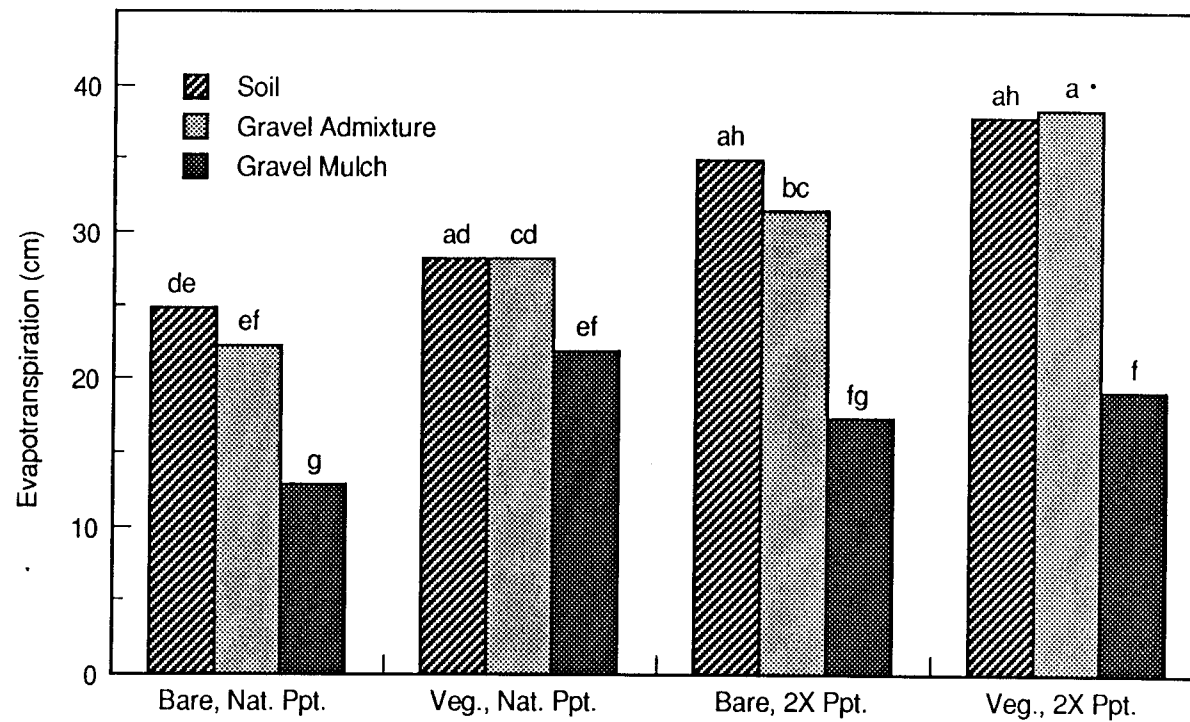
On the October 1989 measurement date, after one complete water cycle, ET was affected by surface treatment, precipitation, and vegetation (Figure 3-7). The gravel mulch treatments had the least amount of cumulative ET, with the lowest value found for the bare, ambient precipitation combination. The gravel mulch/vegetated/ambient precipitation treatment combination had a similar cumulative ET value as both the soil and admix/bare/ambient precipitation treatment combinations. The remaining soil and admix treatment combinations all had significantly greater amounts of cumulative ET than any of the gravel mulch treatments. Vegetation had a significant affect on the gravel mulch/ambient precipitation and for the admix surface treatments under both ambient and twice average precipitation treatments. The amount of precipitation significantly affected the cumulative ET for both soil and admix, but not the gravel mulch treatment combinations.

Storage change at the October 1989 measurement date was positive for three of the four gravel mulch treatment combinations (Figure 3-8), the only exception being the vegetated/ambient precipitation combination. The gravel/vegetated/ambient lysimeters had storage values similar to the bare/soil and admix lysimeters. Precipitation had a significant affect on storage only in the gravel mulch treatments. Vegetation had a significant affect on storage under ambient precipitation conditions for both the gravel mulch and the admix surfaces, and under twice average precipitation for the admix surface treatment. Neither precipitation nor vegetation had significant affects on the storage change in lysimeters with a soil surface.

At the May 1990 sampling date, the cumulative ET from the gravel mulch/bare/ambient precipitation lysimeters was significantly less than from any of the other treatment combinations (Figure 3-9). The twice average precipitation/gravel mulch lysimeters behaved similarly to ambient precipitation soil and admix lysimeters suggesting that proportionately only half of the water input was lost through ET from the gravel mulch lysimeters compared to the soil and admix lysimeters. Within each vegetation/precipitation combination, the cumulative ET amounts were significantly greater from soil and admix surfaces than from gravel mulch surfaces. The amount of precipitation significantly affected cumulative ET for the soil and admix treatments, and for the nonvegetated gravel mulch combinations. The effect of vegetation was significant for gravel mulch surfaces under both precipitation regimes and for admix surfaces under ambient precipitation conditions.

Within each vegetation/precipitation combination, storage change was significantly more positive in the gravel mulch surface lysimeters than in the soil and admix lysimeters (Figure 3-10). The storage change was significantly different among all of the four gravel mulch treatment combinations. Vegetation did not significantly affect the amount of storage change in either the soil or the admix combinations. The amount of precipitation did not significantly affect the amount of storage in the soil surface lysimeters, but did have a significant affect for the admix surface lysimeters.

Total Evapotranspiration from August 1988 - October 1989



Bars labeled with the same letters are not significantly different.

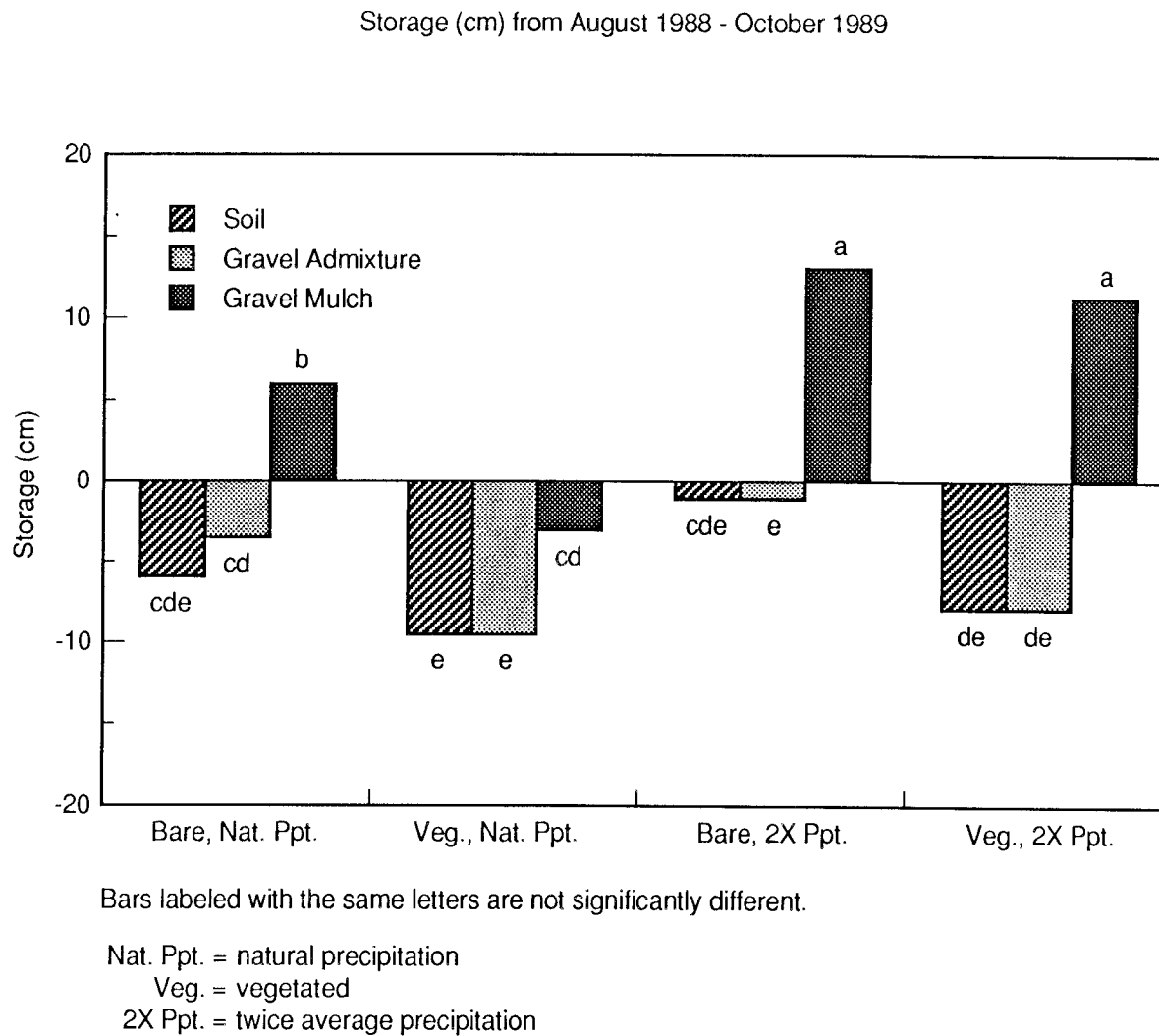
Nat. Ppt. = natural precipitation

Veg. = vegetated

2X Ppt. = twice average precipitation

H9010024.12

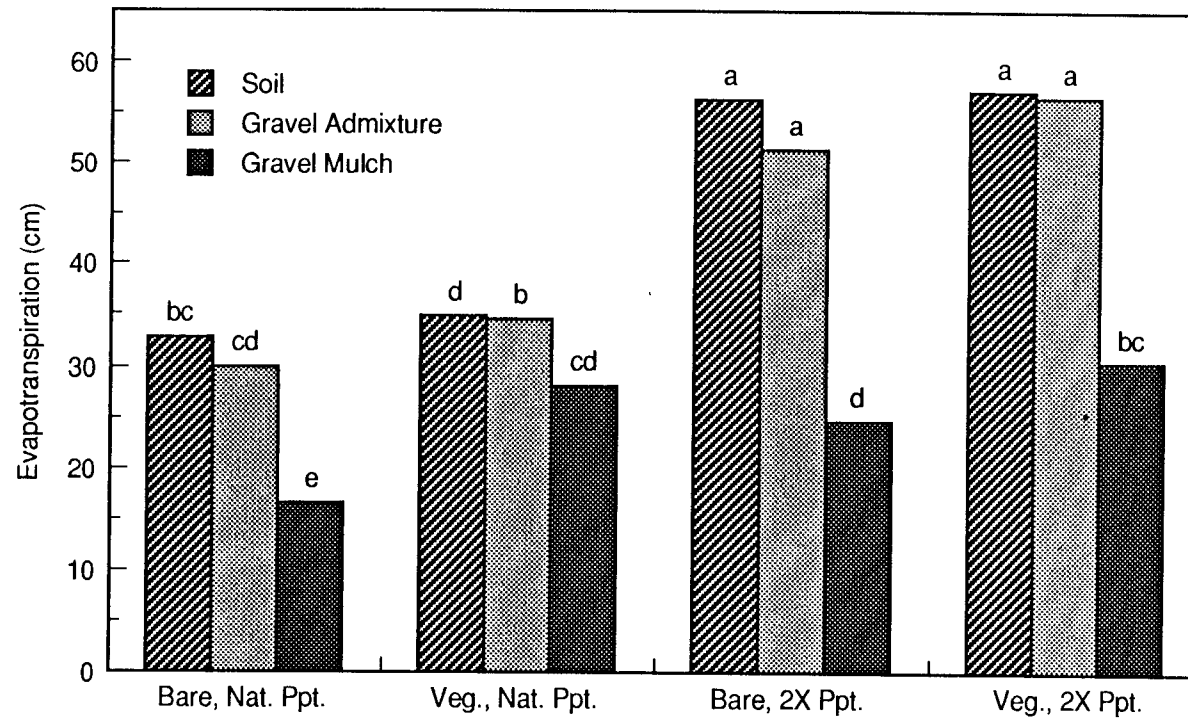
Figure 3-7. Cumulative Evapotranspiration for Three Surface Covers (October 1989).



H9010024.8

Figure 3-8. Storage Change for Three Surface Covers (October 1989).

Total Evapotranspiration August 1988 - May 1990



Bars labeled with the same letters are not significantly different.

Nat. Ppt. = natural precipitation

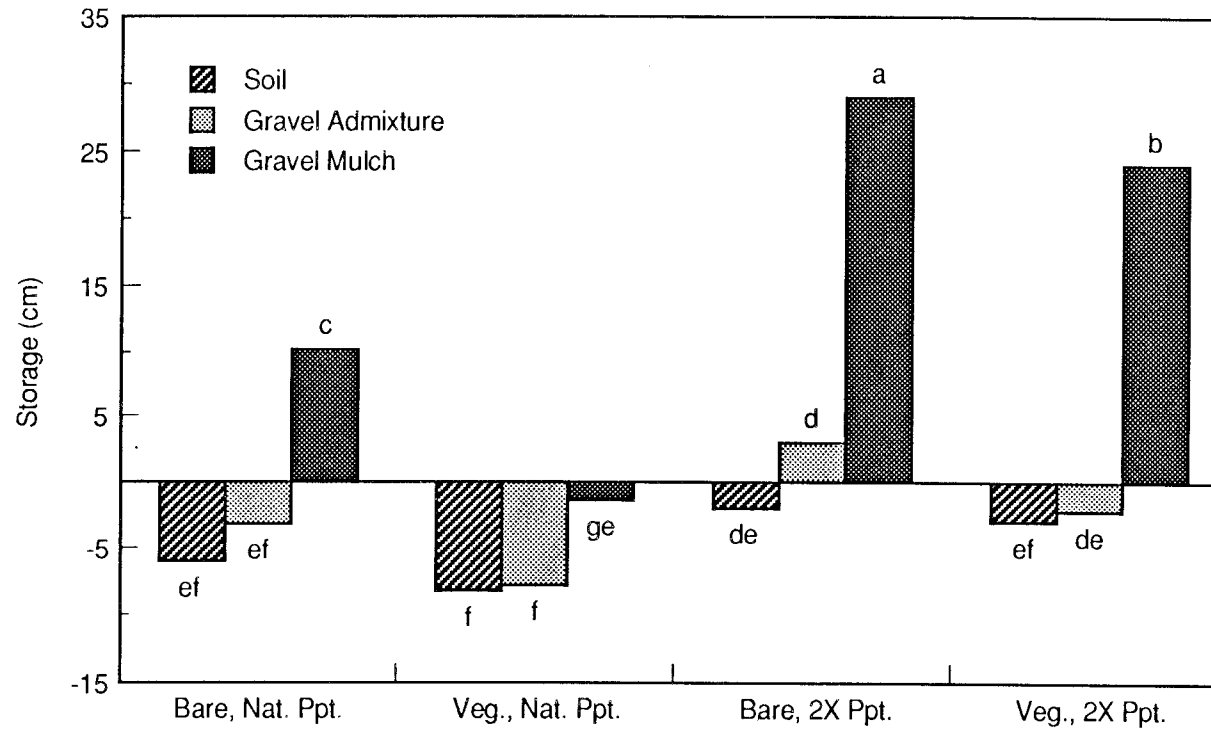
Veg. = vegetated

2X Ppt. = twice average precipitation

H90100024.13

Figure 3-9. Cumulative Evapotranspiration for Three Surface Covers (May 1990).

Storage (cm) from August 1988 - May 1990



Bars labeled with the same letters are not significantly different.

Nat. Ppt. = natural precipitation

Veg. = vegetated

2X Ppt. = twice average precipitation

H9010024.9

Figure 3-10. Storage Change for Three Surface Covers (May 1990).

The ET patterns at the last available sampling date (August 1990) were similar to the May 1990 patterns. Within each vegetation/precipitation treatment combination the gravel mulch surface lysimeters had significantly lower amounts of cumulative ET than either the soil or admix surface lysimeters (Figure 3-11). Vegetation significantly affected the ET in the gravel mulch and the admix surface lysimeters under both of the precipitation regimes. Precipitation had a significant affect on all surface types.

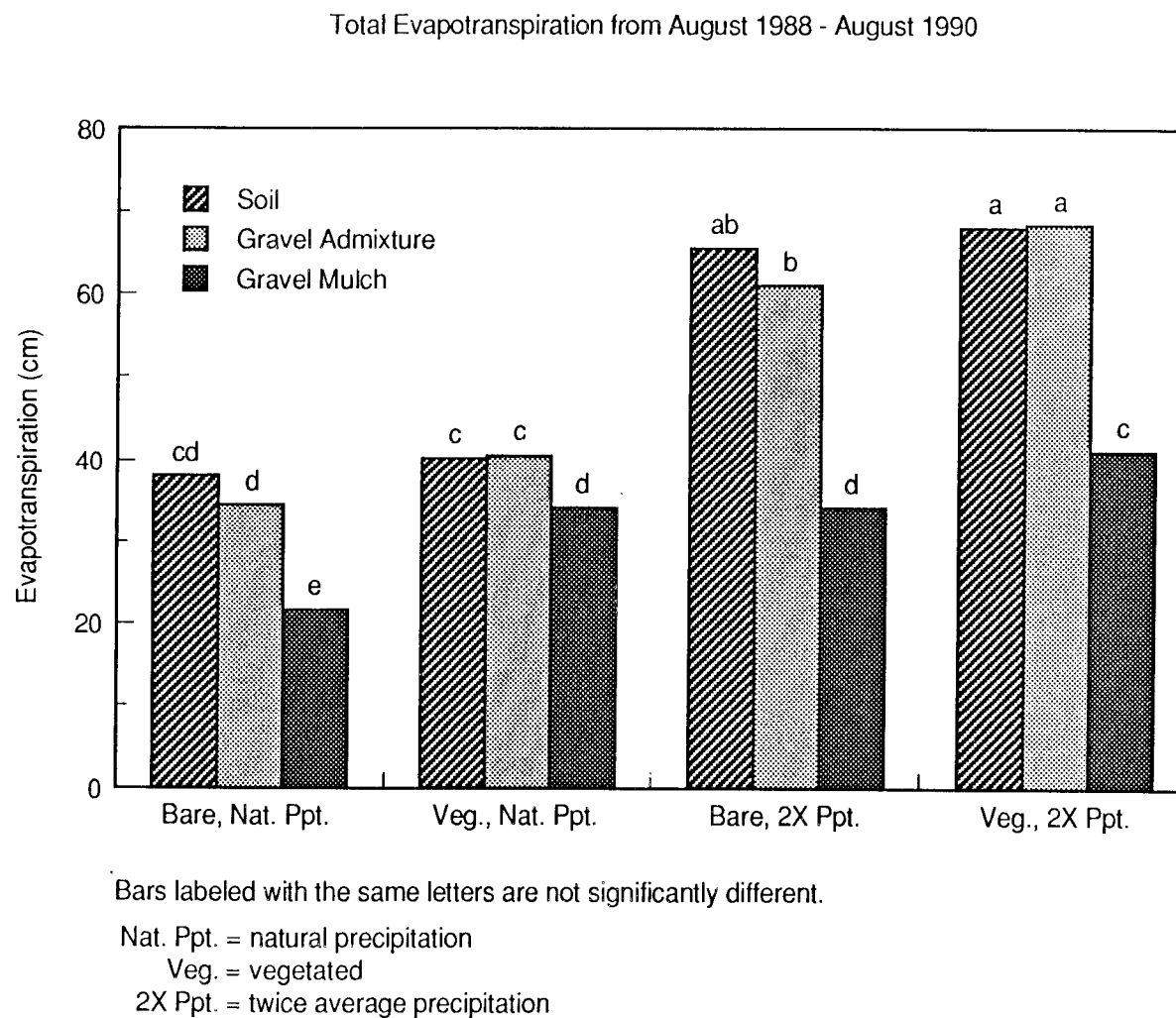
The cumulative storage change patterns at the August 1990 sampling date also were similar to the patterns observed on the May 1990 sampling date. The total storage changes for the four gravel mulch surface treatments were all significantly different from each other (Figure 3-12), with only the vegetated/ambient precipitation treatment combination showing a negative storage change. The amount of precipitation did not significantly affect the storage change for either the soil or the admix surface treatments. Vegetation had a significant affect on storage change for admix surface lysimeters under both precipitation regimes but did not significantly affect the soil surface lysimeters.

The overall conclusions concerning the results described previously include:

- Gravel mulch greatly decreases ET and increases storage compared to soil or admix surfaces
- There is essentially no difference in ET and storage change for bare soil and admix gravel treatments regardless of whether they are vegetated or not
- After about 1 yr of measurement, both the ET and the storage increase under twice average precipitation conditions
- The affects of vegetation are small but real, depending on the particular treatment combinations.

3.2 BARRIER LAYERING SEQUENCE EFFECTS

The treatments with the bimodal and graded capillary breaks had very similar overall patterns of cumulative ET (Figure 3-13) and total storage change (Figure 3-14). The cumulative ET was significantly affected by vegetation only at the sampling dates during the drier parts of the year, October 1989 and August 1990 (Figure 3-15). During May of both 1989 and 1990, vegetation had no significant affect, whereas this affect was significant during October 1989 and August 1990 for the bimodal treatment, and the cumulative ET was slightly higher in the vegetated versus the nonvegetated graded treatment. Within a vegetation treatment there were no significant differences between the bimodal and graded sublayer treatments at any of the analysis dates. The storage changes followed a similar pattern to the cumulative ET (Figure 3-16). All of the treatments had a positive storage change at the May 1989 sampling date and had negative values at the remaining



H9010024.14

Figure 3-11. Cumulative Evapotranspiration for Three Surface Covers (August 1990).

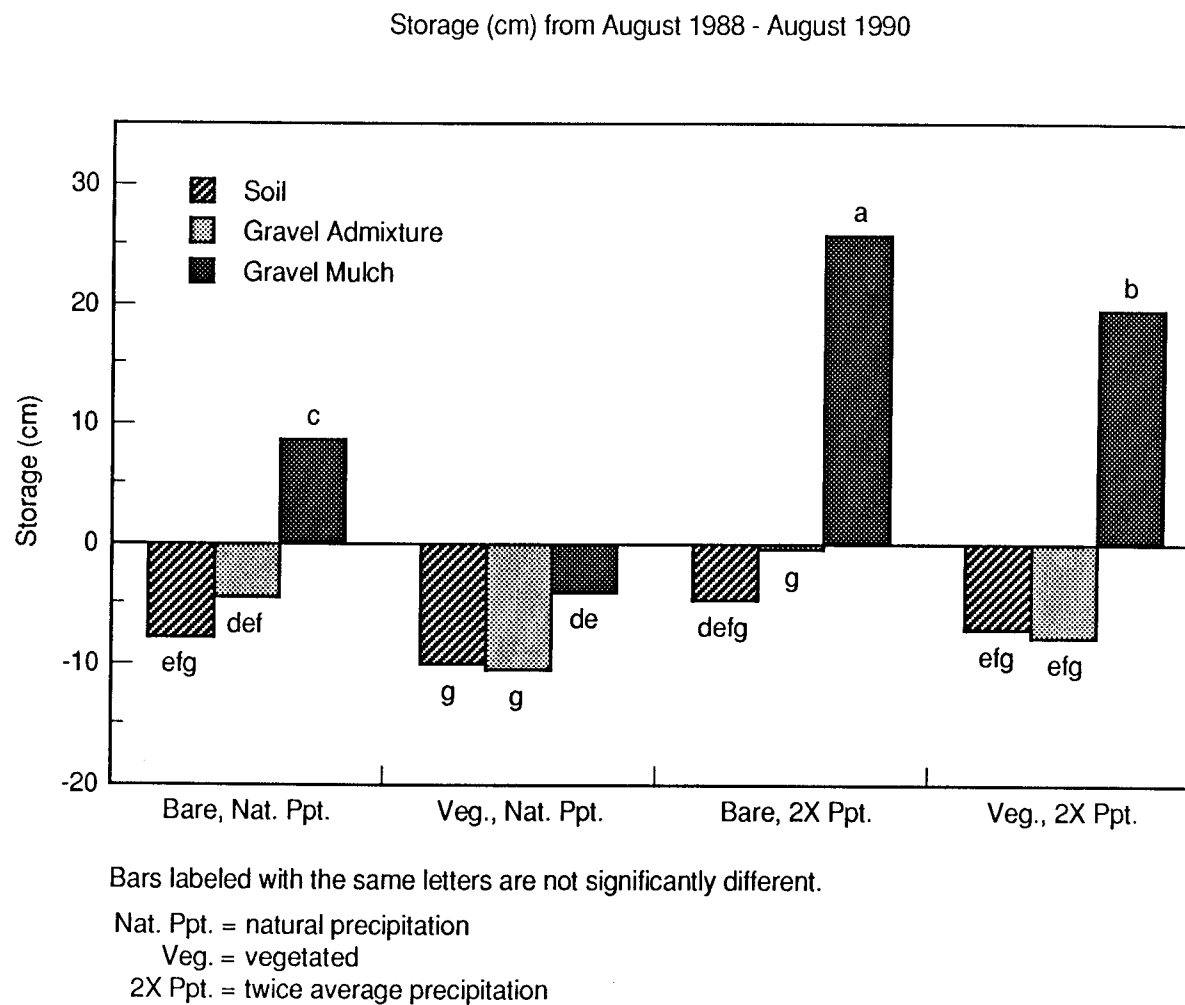


Figure 3-12. Storage Change for Three Surface Covers (August 1990).

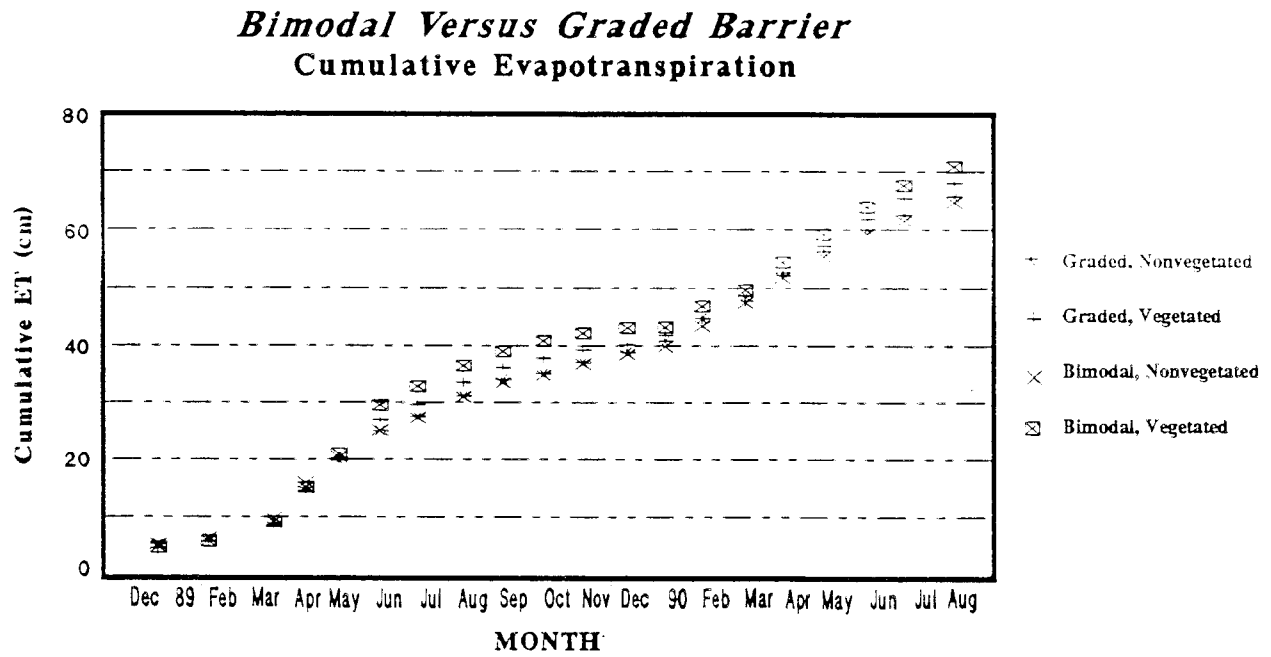


Figure 3-13. Bimodal Versus Graded Barriers (Cumulative Evapotranspiration).

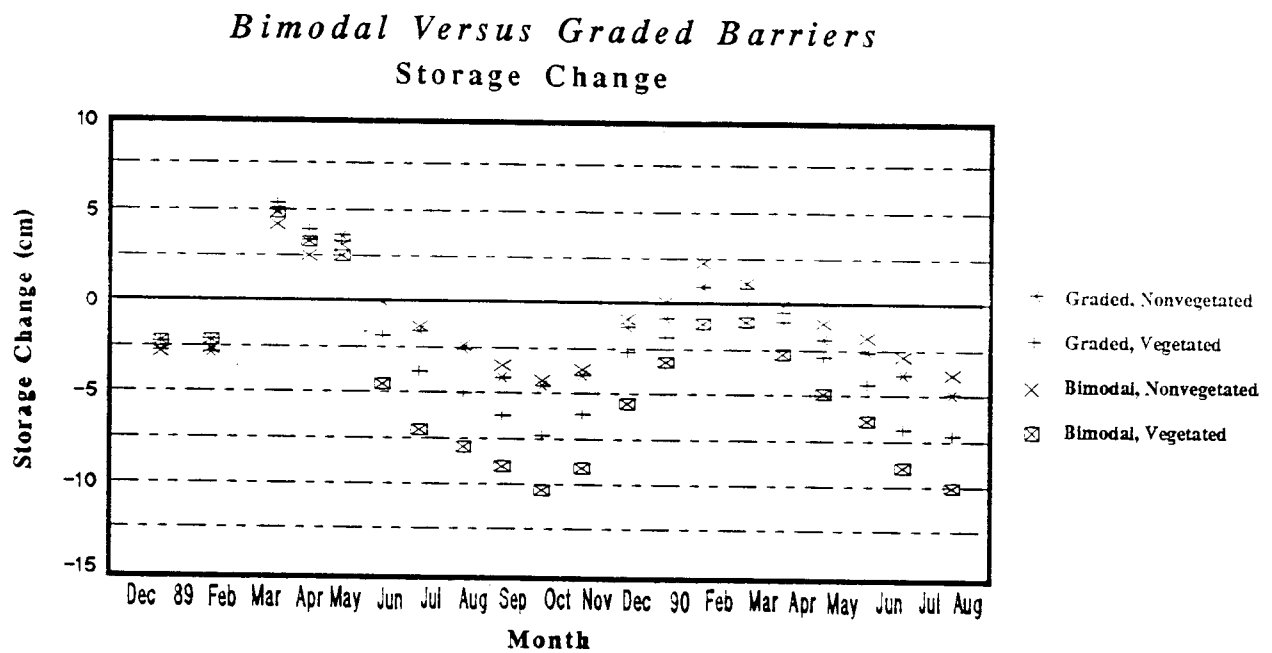


Figure 3-14. Bimodal Versus Graded Barriers (Storage Change).

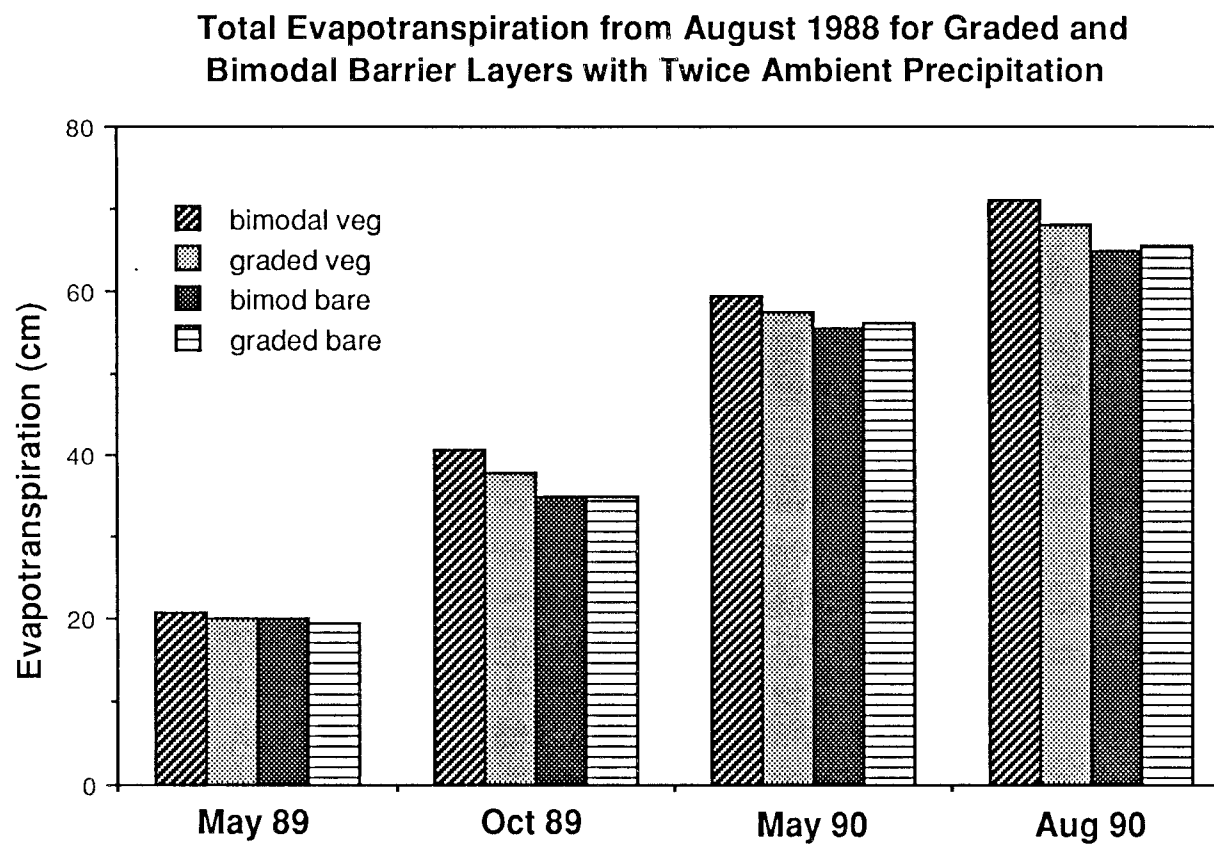
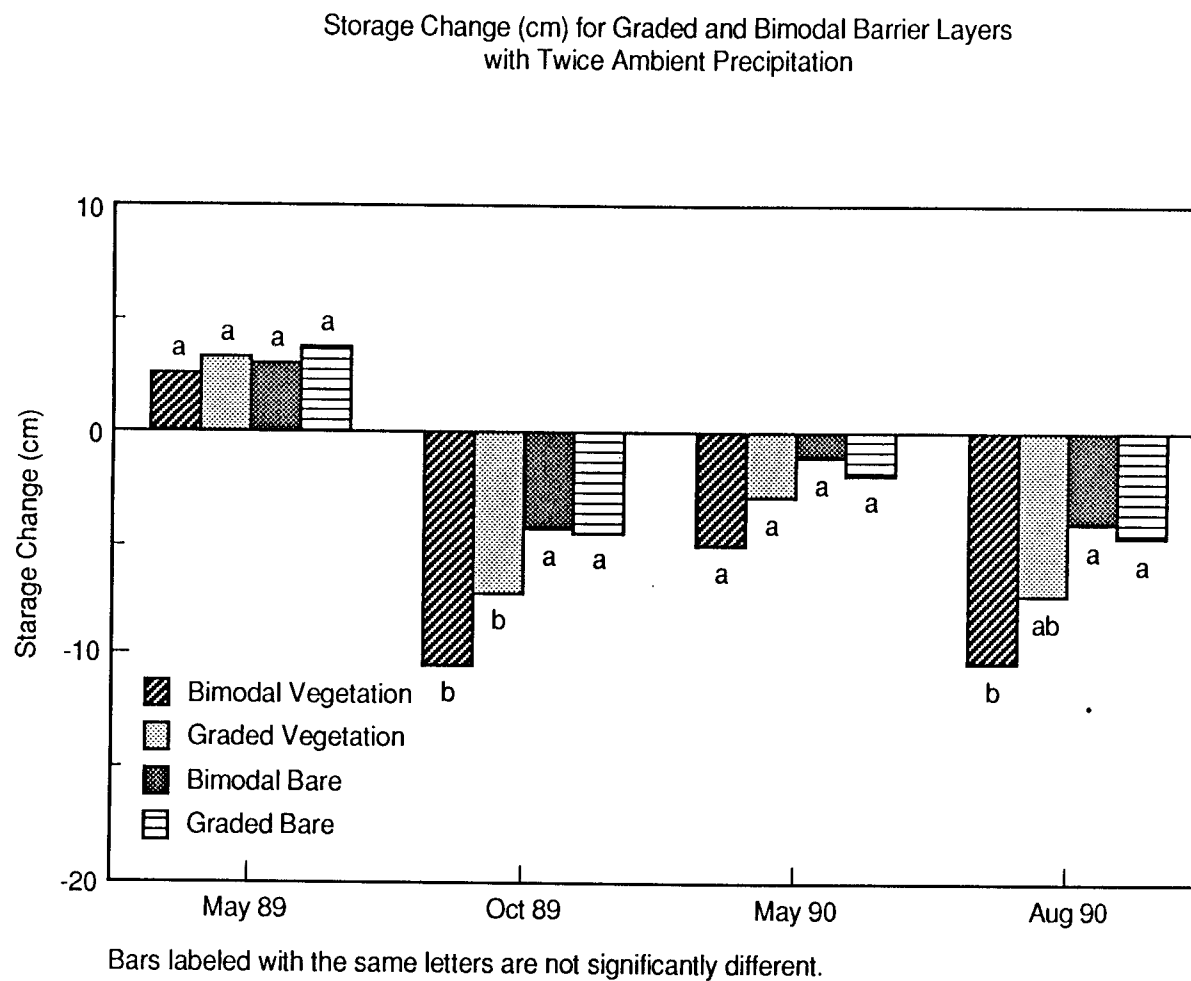


Figure 3-15. Total Evapotranspiration from August 1988 for Graded and Bimodal Barrier Layers with Twice Ambient Precipitation.



H9010024.1

Figure 3-16. Storage Change from August 1988 for Graded and Bimodal Barrier Layers with Twice Ambient Precipitation.

analyzed dates. The vegetated lysimeters had greater storage change (decrease) than the nonvegetated lysimeters during October 1989 and August 1990. This difference was significant in the bimodal treatment but was not for the graded treatment.

The difference between the graded and bimodal treatments concerning vegetation may be attributable to the amount of plant biomass available and not to any intrinsic affect of the layering sequence itself. No drainage was detected in any of the graded or bimodal treatment lysimeters.

3.3 SAND AND GRAVEL DEPOSITION

The original analysis of variance model (Relyea et. al 1990) compared the sand deposition treatments with the control twice average precipitation plain soil surface treatments, with the effects of vegetation also included. During initial data analysis we were struck by the similarity between the sand treatments and corresponding gravel surface treatments. Therefore, we have included the gravel mulch treatments in this analysis, with a resulting 3 by 2 factorial ANOVA with three levels of surface treatment (sand, gravel, and control) and two levels of vegetation. This is a complete, balanced model.

The long-term patterns in cumulative ET and storage change are presented in Figures 3-17 and 3-18, respectively. From these figures it is readily apparent that compared to the control, plain soil treatments, there is considerably less ET and greater storage in all of the sand or gravel mulch treatments.

When cumulative ET values are compared at specific dates (Figure 3-19) the amounts of ET are significantly less with sand or gravel covers than with plain soil at all sampling dates. Vegetation was never a significant affect in the soil surface lysimeters, but became significant for the sand and gravel treatments during the second year of measurement. Changes in storage show a similar pattern (Figure 3-20). Decreased storage in the presence of vegetation was evident during the second year of sampling for the sand and gravel surface treatments, but vegetation was not a significant affect on the control surface treatment. When comparing the sand and gravel treatments, there were no significant differences within any vegetation treatment/sampling date combination.

Drainage was observed from the sand deposition and irrigated gravel mulch lysimeters. Cumulative drainage for these treatments ranged from about 0.6 cm to 1.1 cm as of the August 1990 sampling date, with initial drainage first being detected during January 1990 (Figure 3-21). None of the mean cumulative drainage amounts are significantly different among the gravel and sand surface treatments. These were the only lysimeter treatments that were found to produce drainage during the two years of sampling.

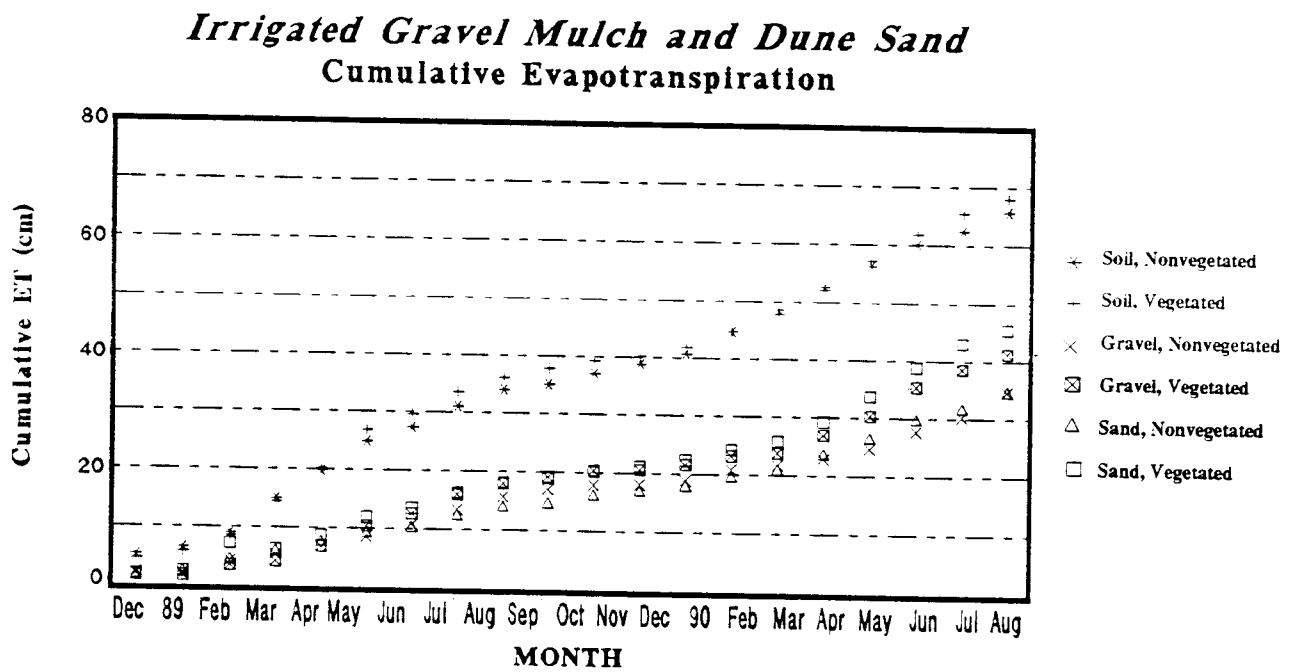


Figure 3-17. Irrigated Gravel Mulch and Dune Sand (Cumulative Evapotranspiration).

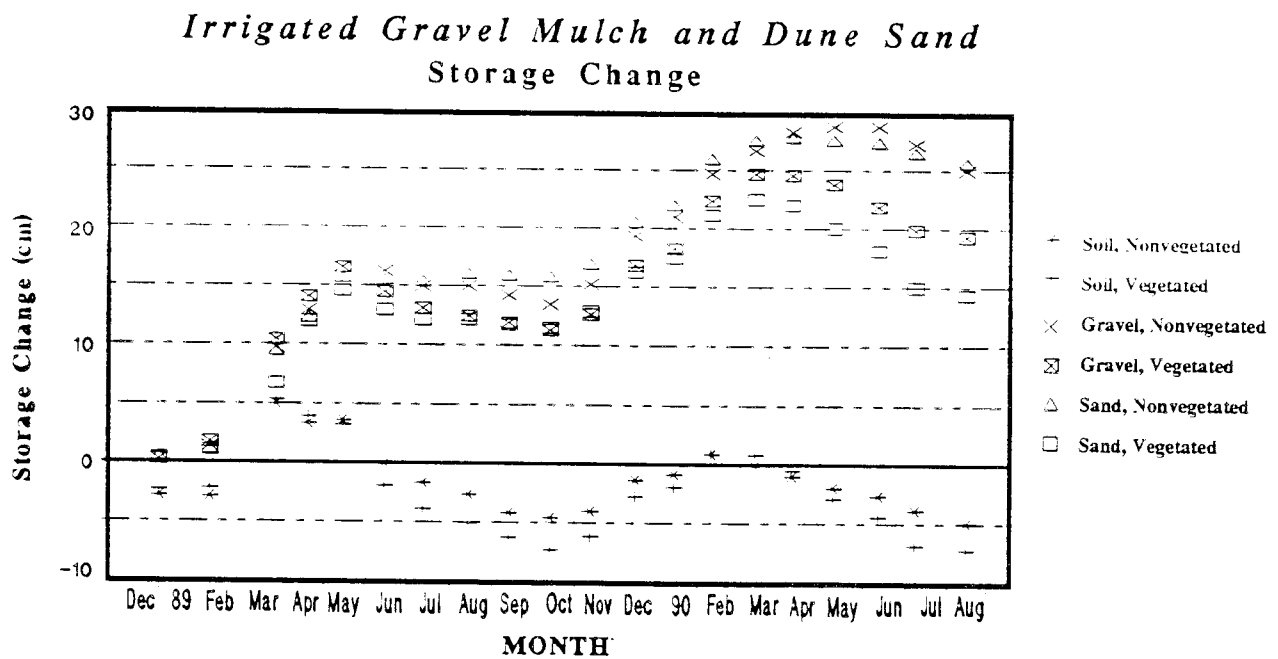
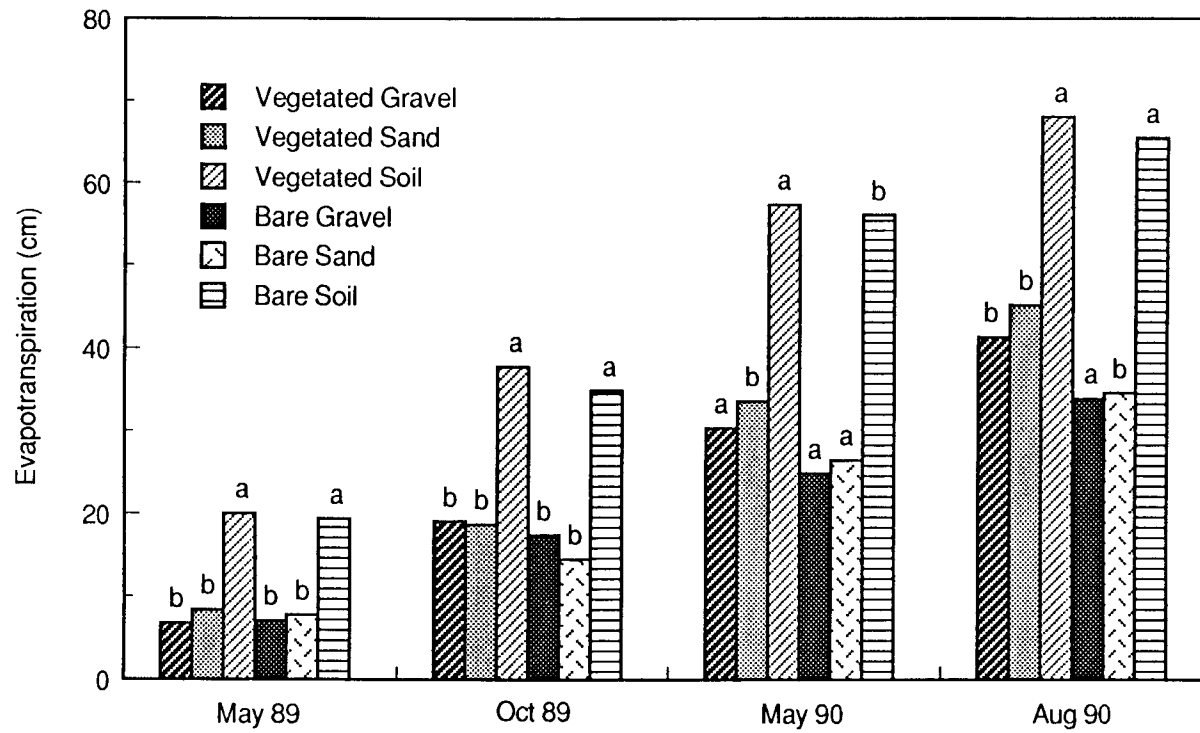


Figure 3-18. Irrigated Gravel Mulch and Dune Sand (Storage Change).

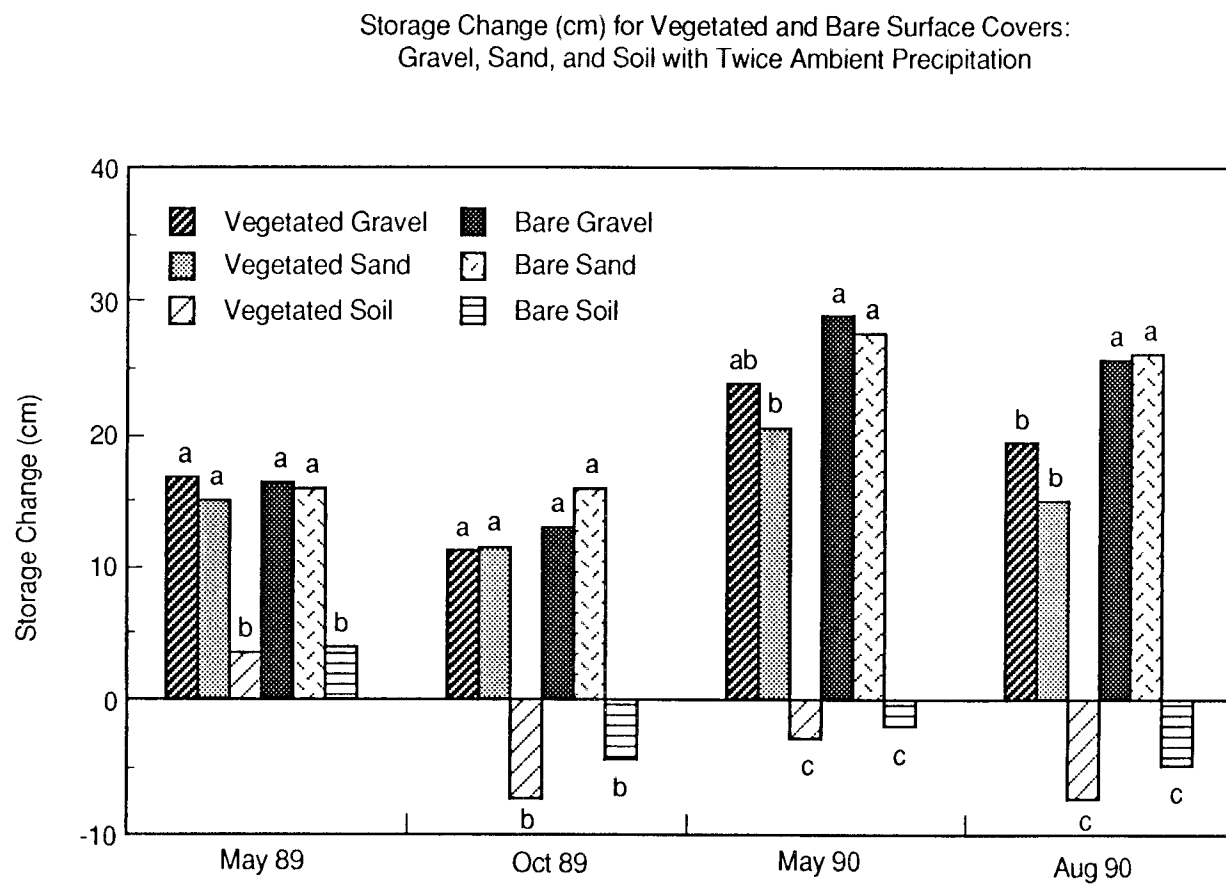
Total Evapotranspiration (cm) for Gravel, Sand, and Soil Surface Treatments
with Twice Ambient Precipitation



Bars labeled with the same letters are not significantly different.

H9010024.6

Figure 3-19. Cumulative Evapotranspiration from Gravel, Sand, and Soil Surface Lysimeters on Selected Sampling Dates.



Treatment means ($n = 5$) within date categories showing the same letter are not significantly different ($\alpha = 0.05$).

H9010024.2

Figure 3-20. Storage Change for Gravel, Sand, and Soil Surface Lysimeters on Selected Sampling Dates.

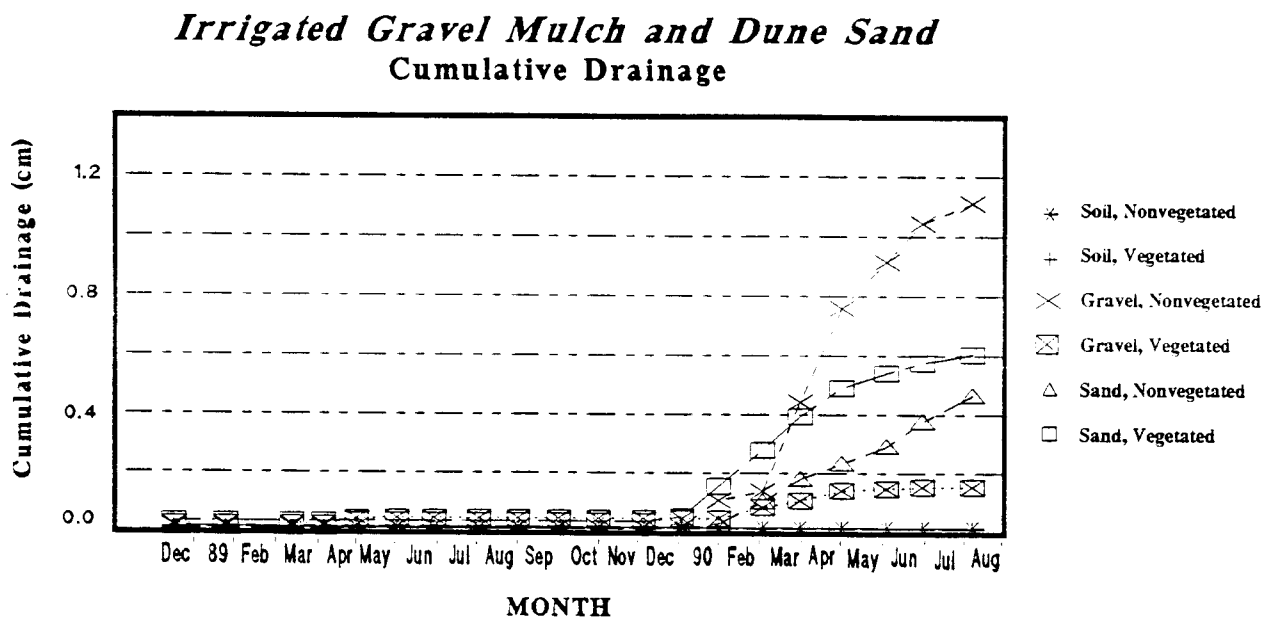


Figure 3-21. Irrigated Gravel Mulch and Dune Sand (Cumulative Drainage).

3.4 ALTERNATIVE INFILTRATION BARRIERS

There is little difference among the clay, grout and control treatments in the long term patterns of either cumulative ET (Figure 3-22) or in total storage change (Figure 3-23). In the analysis of the results at the selected sampling dates, the only significant difference in cumulative ET occurred early in the experiment in May 1989 (Figure 3-24). Likewise, this sampling date is the only one that showed significant storage change differences (Figure 3-25). The grout treatment had significantly higher cumulative ET and lower total storage than either the bimodal control or the graded design. The means for the clay layer lysimeters were between these two extremes and were not significantly different from either. The different appearance early on in the experiment may be the result of the high water content of the grout slurry used to form the grout layer (Relyea et al. 1990). The drying of this layer may have provided the extra moisture for the increase in ET. The same would be true to a lesser extent in the lysimeters with a clay layer. No drainage was detected in any of these alternative barrier lysimeters.

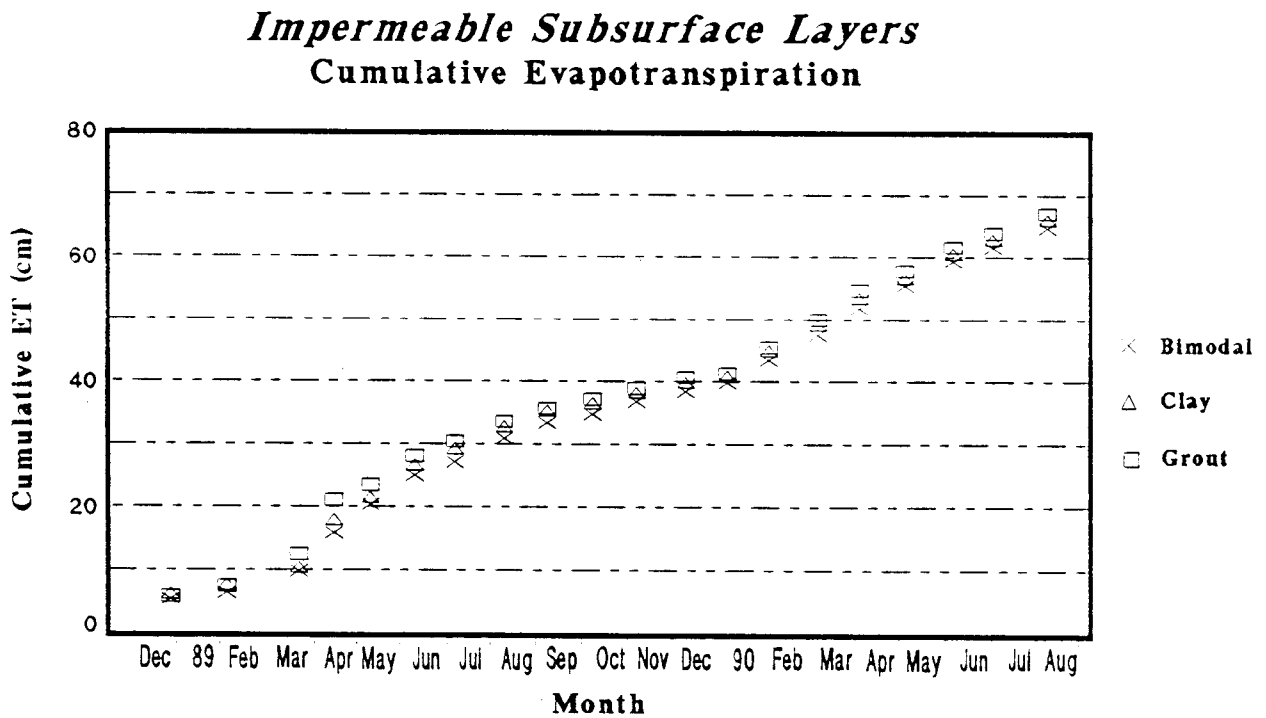


Figure 3-22. Impermeable Subsurface Layers
(Cumulative Evapotranspiration).

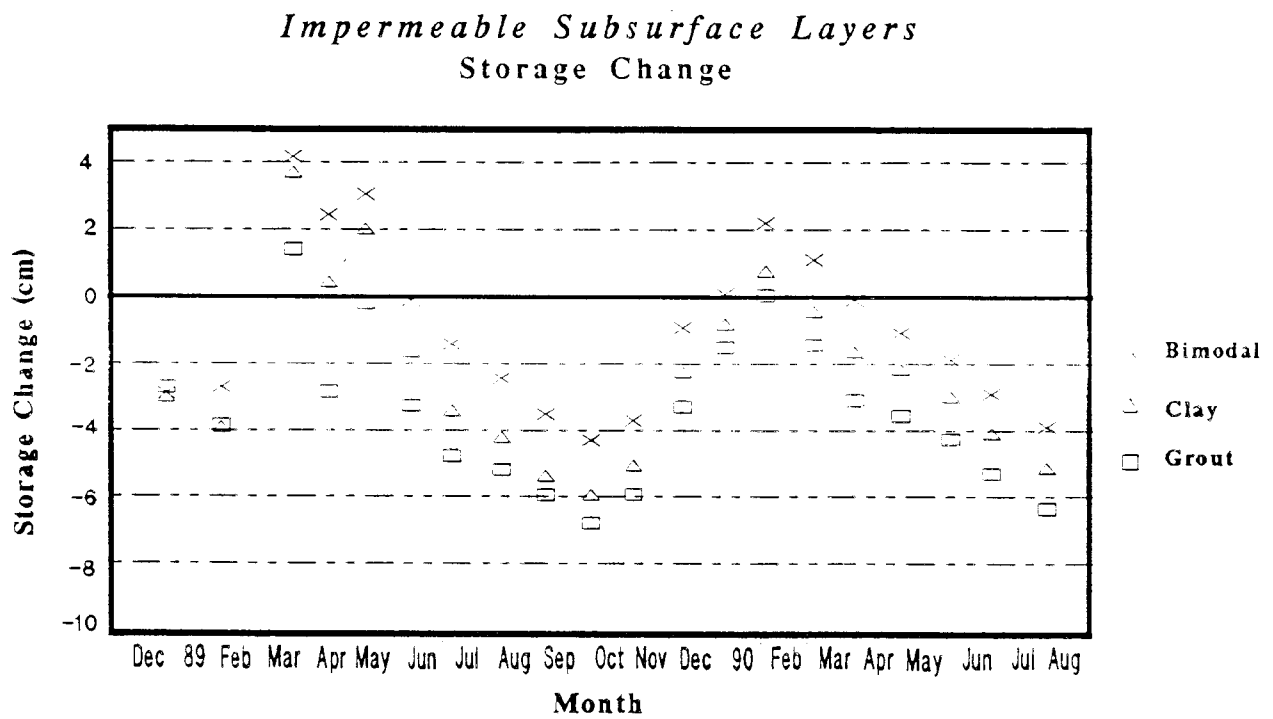
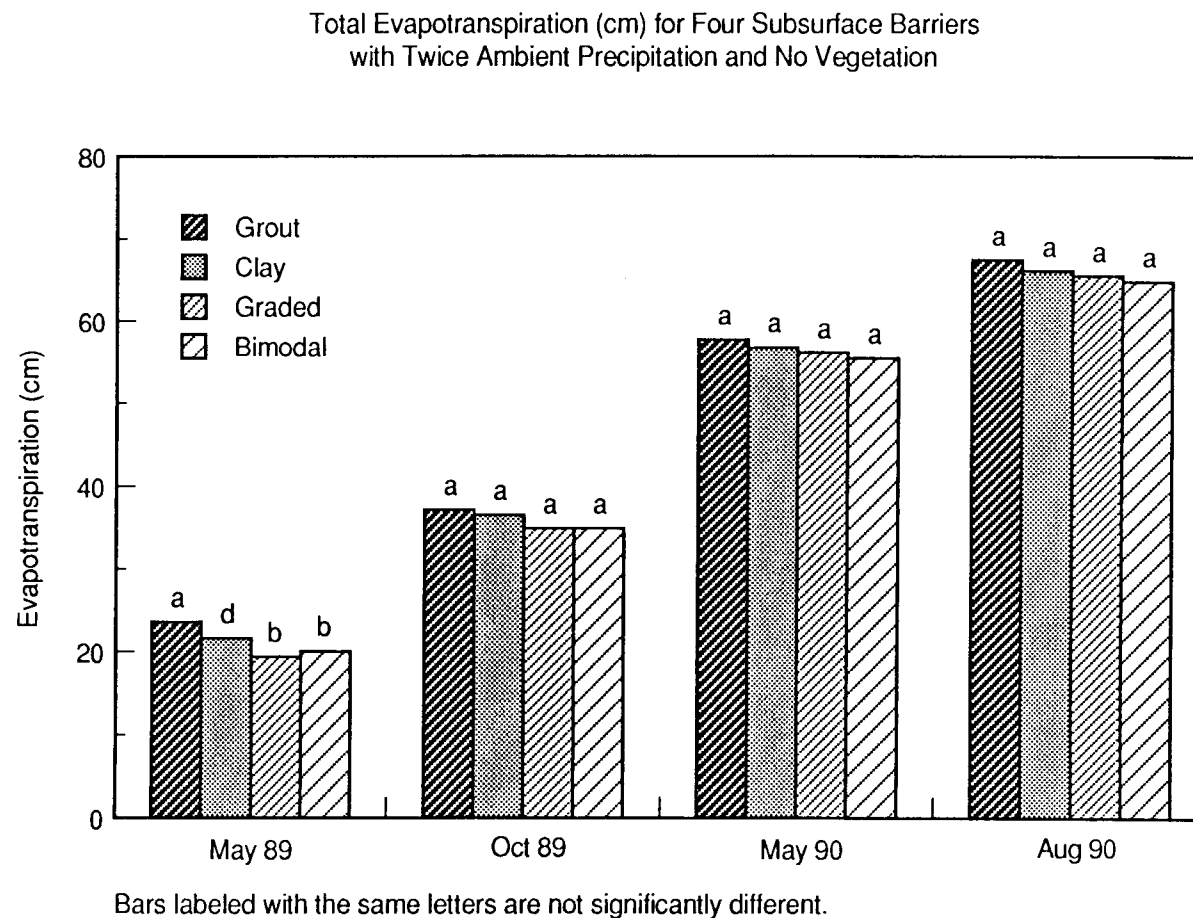
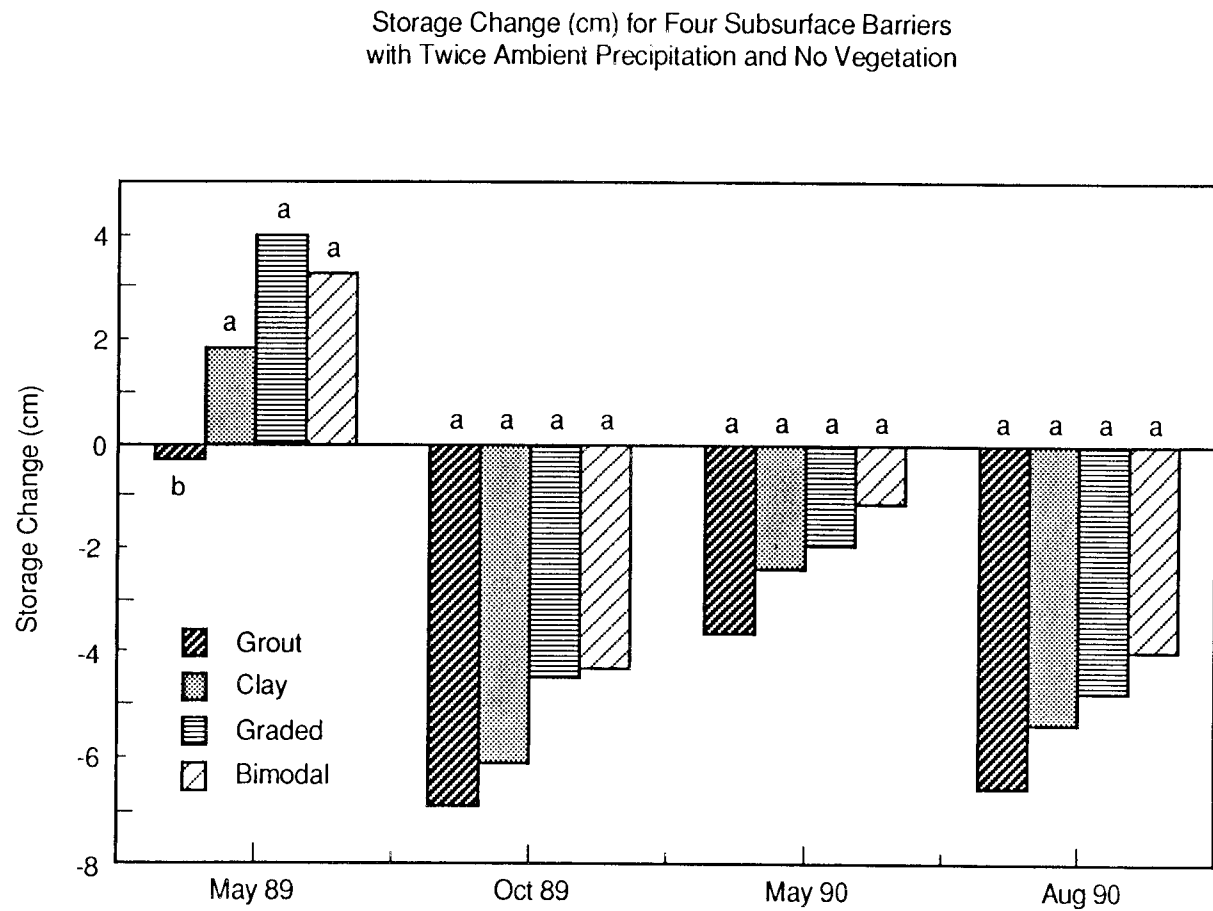


Figure 3-23. Impermeable Subsurface Layers (Storage Change).



H9010024.5

Figure 3-24. Cumulative Evapotranspiration Clay, Grout, and Control Lysimeters on Selected Sampling Dates.



H9010024.3

Figure 3-25. Storage Change for Clay, Grout, and Control Lysimeters on Selected Sampling Dates.

4.0 SUMMARY AND CONCLUSIONS

Drainage did not occur in any lysimeters with soil or gravel admix surfaces, or in lysimeters with a gravel mulch surface and ambient precipitation. Thus, total precipitation during the first 2 yr of the experiment has effectively been partitioned into ET and storage. For the bare soil and admix treatments ET, exceeded precipitation and there was a net reduction in stored water. These preliminary results suggest that soil and gravel admix (pea gravel mixed into the McGee Ranch silt loam) are equally effective in returning soil water to the atmosphere through the combined processes of evaporation and transpiration. Only the sand and gravel mulch treatments resulted in a net gain in soil water storage. This observation suggests that gravel surface mulch (that could be applied to soil surfaces to limit erosion) and sand (that might accumulate as deposition on the barrier surface) may limit ET to the extent that water will accumulate in the barrier and eventually contribute to drainage, particularly under conditions where vegetative growth is minimal or absent.

Actually, the performance of the subsurface alternative infiltration barriers and the different layering sequences was not effectively tested because the surface treatment applied (soil only) provides for the evaporation of all precipitation, even at twice the average amount. Therefore, it is anticipated that the additional water applications planned for FY 1991 may initiate increases in storage thus permitting a more complete evaluation of solution grout, clay, and bimodal layering sequences in limiting drainage.

The addition of inflatable insulating collars just below the soil surface between the lysimeter sleeves and the lysimeters was effective in moderating rapid fluctuations in lysimeter soil temperature and in causing the lysimeter soil temperatures to track temperatures in the surrounding soil instead of the air.

Although vegetation growth was not directly measured on the lysimeters in FY 1990, the relative quantity of growth was visually observed to be comparable to that in FY 1989. The vegetation quantity can best be described as sparse, and was well below the amount expected under natural field conditions. Thus, the vegetation treatments approximate a lower limit of cheatgrass productivity which suggests that transpiration in the lysimeters is low compared to potential transpiration that may occur on future barrier surfaces. Also, cheatgrass communities are relatively shallow-rooted and have been reported to use less water than a sagebrush-bunchgrass community occupying the same site (Cline et al. 1977).

Nutrient deficiencies are suspected to be a contributing factor for the limited plant growth that was observed. Nutrient deficiencies may result if the soil came from deeper zones within the native soil profile at the McGee Ranch. Future tests will compare the nutrient status of the lysimeter soil with the native soils at the McGee Ranch. Other limiting factors may include the degree of soil compaction or the abundance of mycorrhizae in the soil. These factors also may be addressed in the future. In order to obtain a more representative vegetation cover and associated vegetation responses,

the plan is to provide enhanced vegetation growth in FY 1991 by (1) adding nutrients to the lysimeters, (2) changing the vegetation by planting other species, or (3) both of the above. The establishment of normal plant cover on the lysimeters also is important if representative test results are to obtain on protective barrier performance with respect to ET, soil water storage, and drainage under enhanced (three to four times average) precipitation.

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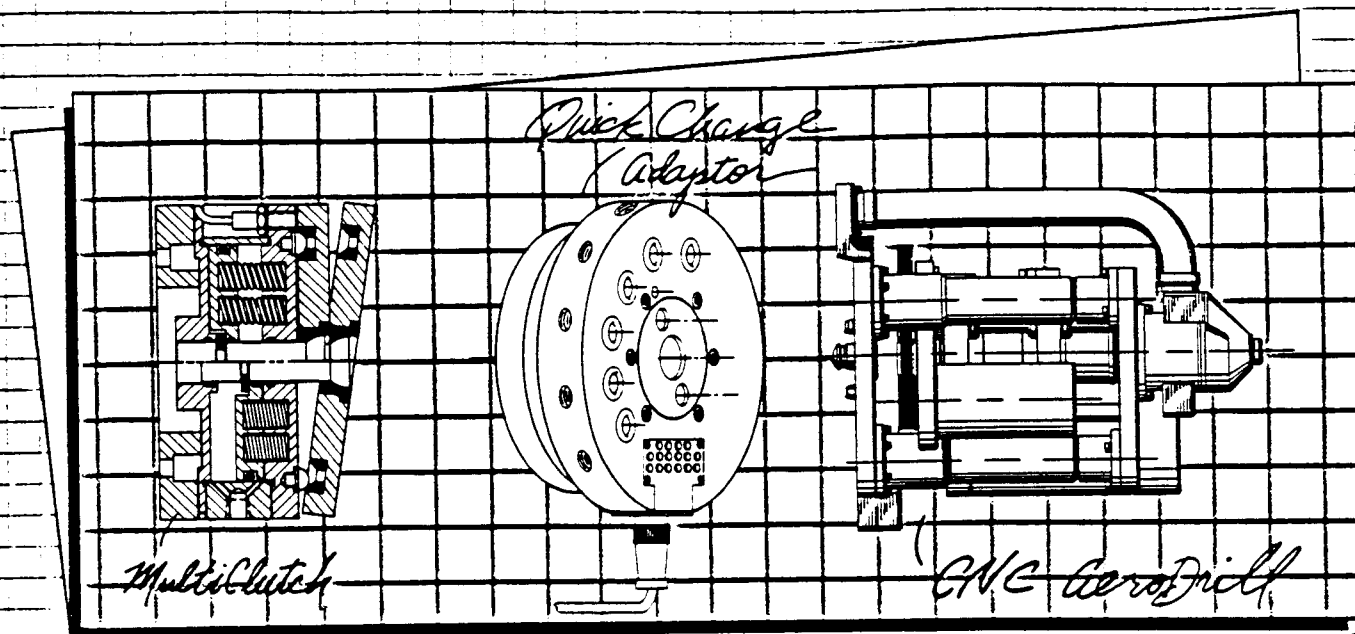
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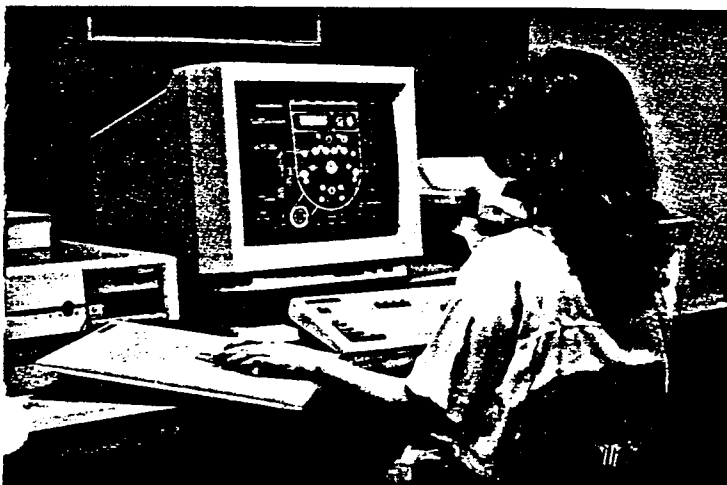
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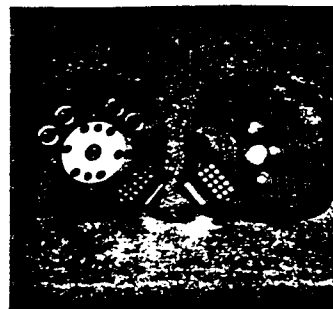


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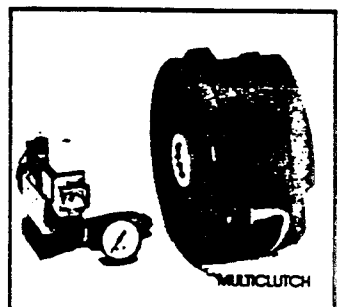
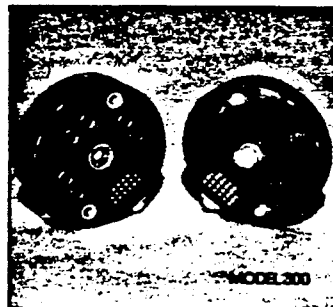
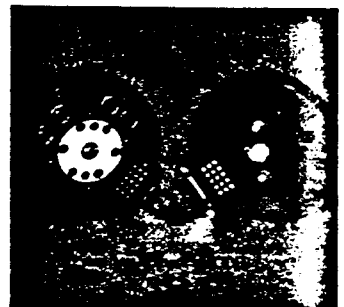
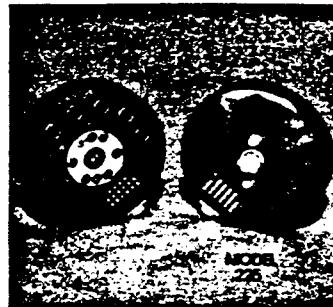
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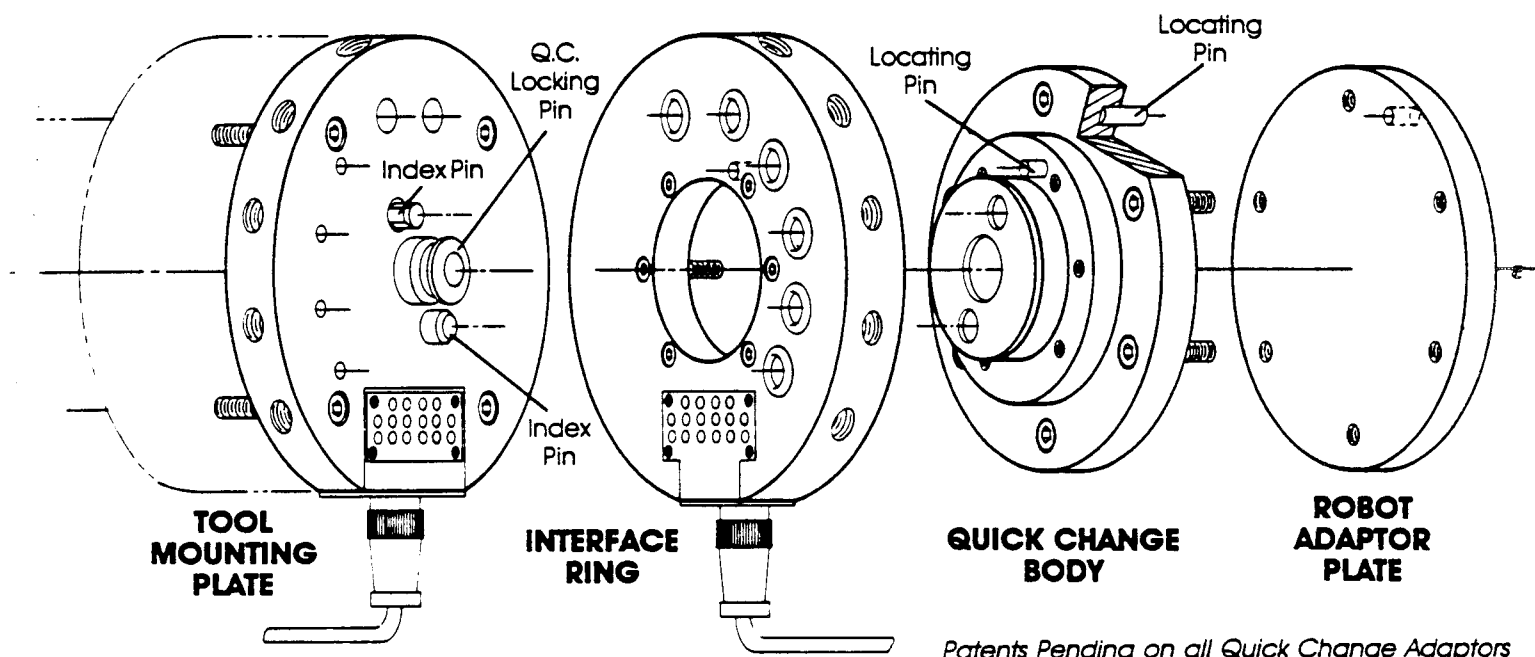
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EOA's Family of Quick Change Adaptors. Stunning simplicity combined with cost effectiveness.

EOA Systems, Inc. has developed a family of Quick Change Adaptors designed to pick up and replace a variety of tools within a single work cell. EOA's Quick Changes are the most extensive offering in the robotics industry with payloads ranging up to 300 lbs. In addition, the Quick Changes are very versatile in that they can be mounted on any commercially available industrial robot.

The design of the Quick Change represents a thorough understanding of rigorous manufacturing environments. As the illustration depicts, the Quick Change is of modular construction which will greatly facilitate its assembly and disassembly while on the factory floor. The unique locating pins on the rear and face of the Quick Change Body allow the user to remove it from the robot and precisely replace the Quick Change in its previous position. By placing the Quick



Patents Pending on all Quick Change Adaptors

Change in the precise location every time, production personnel avoid the time consuming process of robot re-programming following removal of the Quick Change. Modular construction and the locating system are two of the many reasons the Quick Change is capable of high performance — year after year — in the most demanding production situations.

Another key advantage of the Quick Change is its stunning simplicity of operation. So simple, in fact, that only one moving part is needed. The Quick Change can manipulate over 40 times its weight by utilizing a fail-safe, tool steel locking mechanism. This incredible strength is due to the design of the locking mechanism located internal to the Quick Change Body which distributes both horizontal and vertical load forces evenly. By not allowing load forces to "collect," the Quick Change can manipulate much greater payloads with a minimum of stress.

The Tool Mounting Plate is also designed with simplicity and cost effectiveness firmly in mind. Because of the multitude of Tool Mounting Plates needed, the user must carefully evaluate the costs associated with this aspect of interchangeable tooling. EOA Systems understands this and has designed the Tool Mounting Plate to incorporate a minimum of components. The Quick Change couples in a very straightforward manner by fitting over the short Quick Change locking pin. Notice the design of the Quick Change locking pin — short for ease of programming and designed to allow a **1/8" (3.17mm) "coupling window."** This allows the Quick Change to couple when within 1/8" (3.17mm) of the Tool Mounting Plate surface, thus allowing the robot programmer some leeway in the programming of the robot.

The Quick Change couples around the Quick Change locking pin while using the tool steel index pins for location and to resist radial movement. The coupling process is very rapid with an elapsed time of .5 seconds. In addition to providing strength, the index pins and Quick Change locking pin also maintain the repeatability of the Quick Change to within $\pm .001"$ (0.025mm). The simplicity of the EOA Systems Quick Change Adaptor makes for easy operation and maintenance while the precise repeatability of this unit allows the most exacting applications to be easily performed.

All models of modular design except Model 300 Series.

MODEL 25

The Model 25 Quick Change Adaptor has been designed for use on light payload assembly and process robots. Manufactured from lightweight delrin, the Model 25 can manipulate a maximum payload with a minimum tooling weight. The short overall length of the Model 25 translates into much less deflection at the tool point. This is an important criterion especially considering the strict repeatability requirements of small assembly applications. The spring loaded electrical contacts ensure maximum contact pressure with a minimum of friction when uncoupling the Model 25 Quick Change Adaptor.

ADAPTOR PLATE

ENGINEERING SPECIFICATIONS

Combined* Height: 2.25" (57.15mm)

Combined* Weight: 1.8 lbs.

Payload: 25 lbs. (11kg)

Moment: 300 in.-lbs.
(34N-M)

Position

Repeatability: $\pm .001"$

Material: Delrin,

Tool Steel

Operating Pressure: 70 PSI (483kPa),
4-way valve

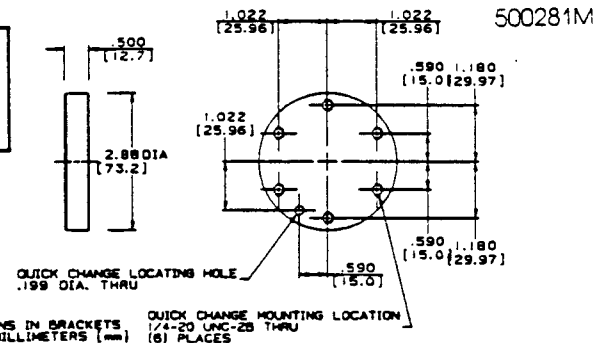
* Represents combined height and weight of
Quick Change assembly and Tool Mounting Plate when coupled.

INTERFACE PACKAGES

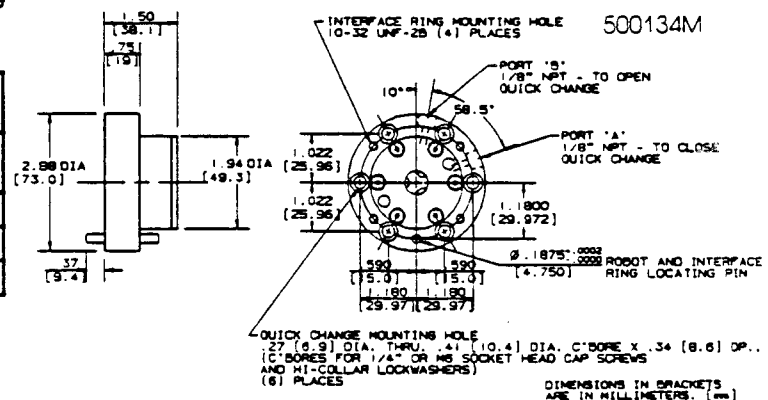
Interface Package	Ports	Port Size (NPT)	Electrical Contacts	Rating
A	4	2 - 3/8" 2 - 1/4"	15	5 amps, 120V
B	6	1/4"	15	5 amps, 120V
C	2	10-32	15	5 amps, 120V
D	4	1/8"	15	5 amps, 120V

NOTE: EOA supplies at no extra charge 6 ft. (1.8M) of 15 conductor cable with each quick change assembly and 1 ft. (.3M) of 15 conductor cable with each Tool Mounting Plate.

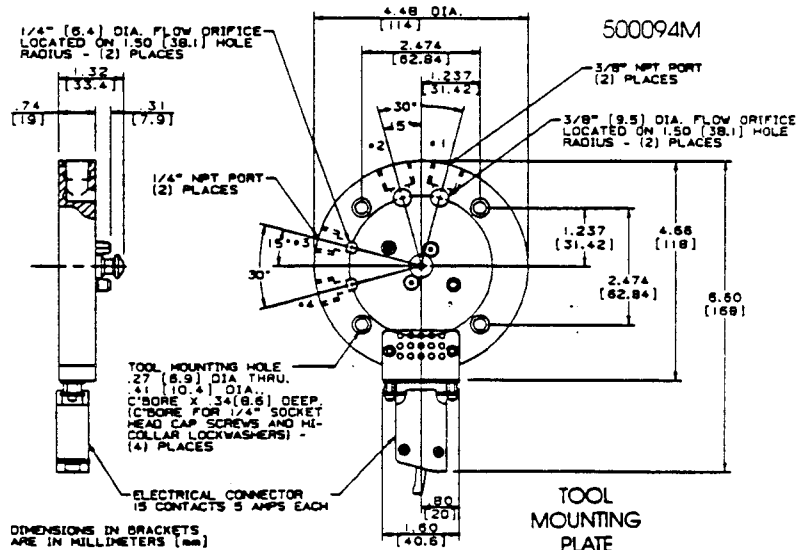
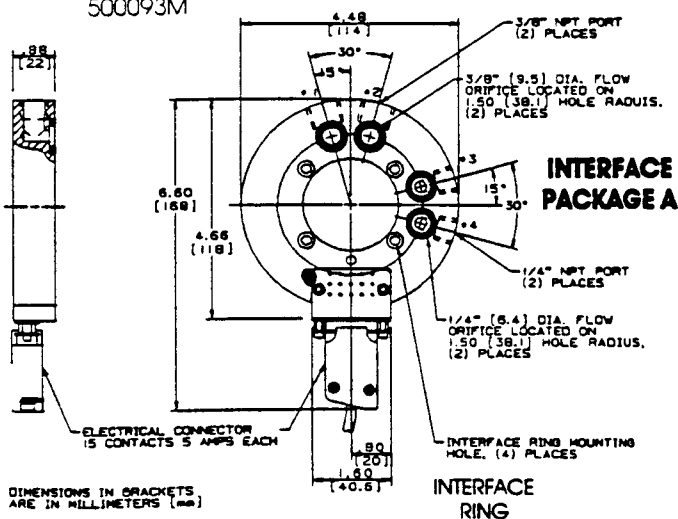
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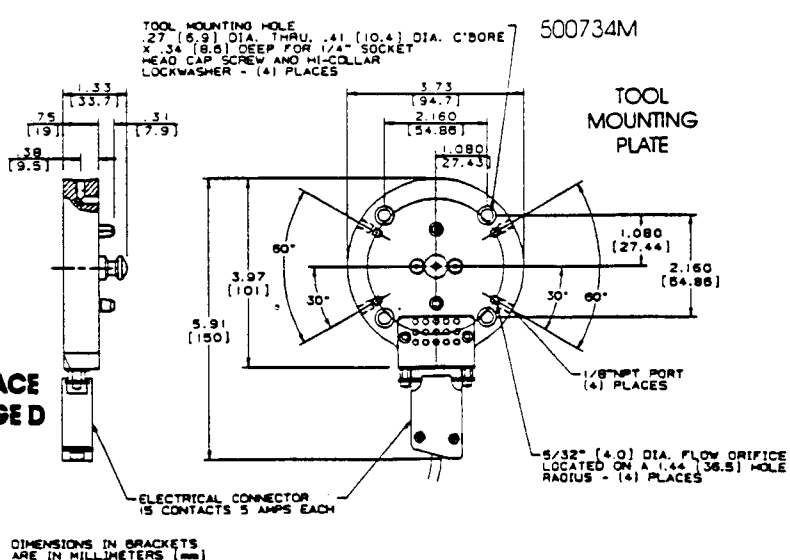
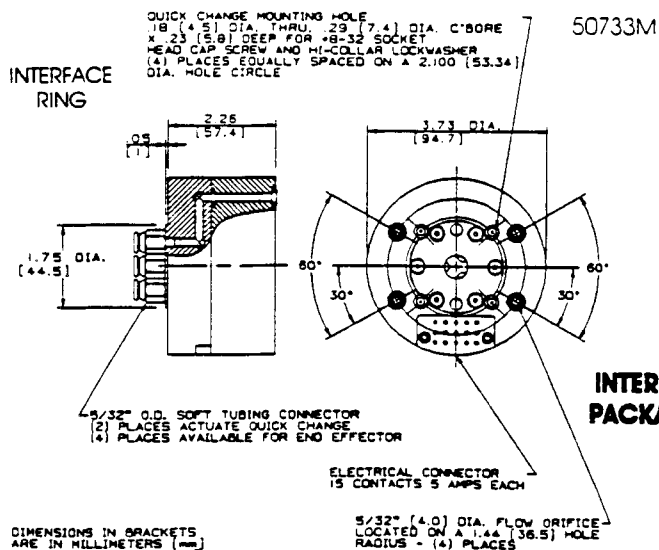
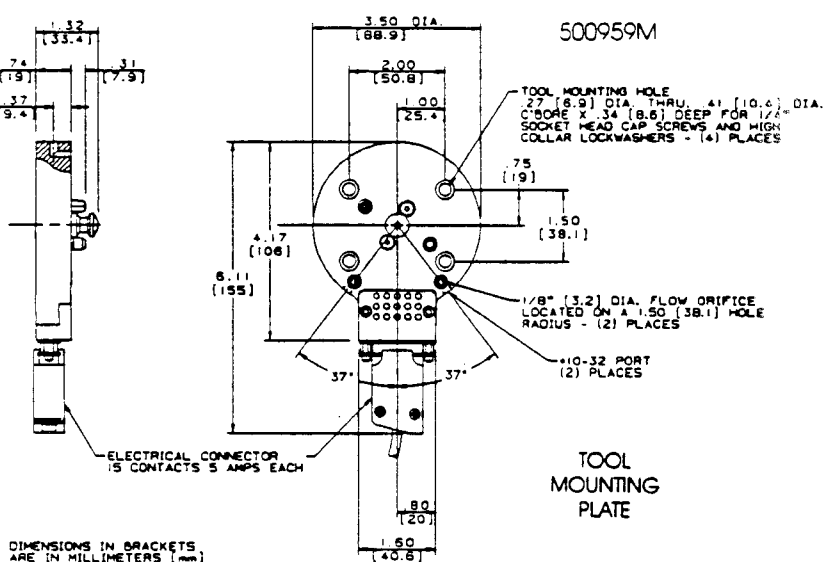
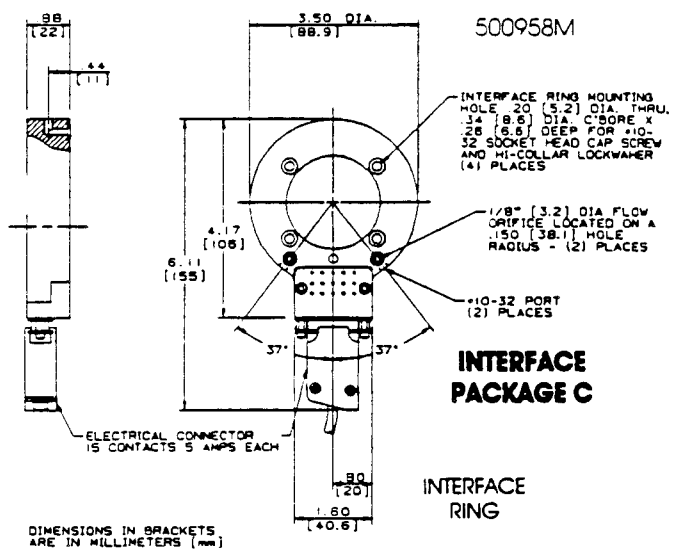
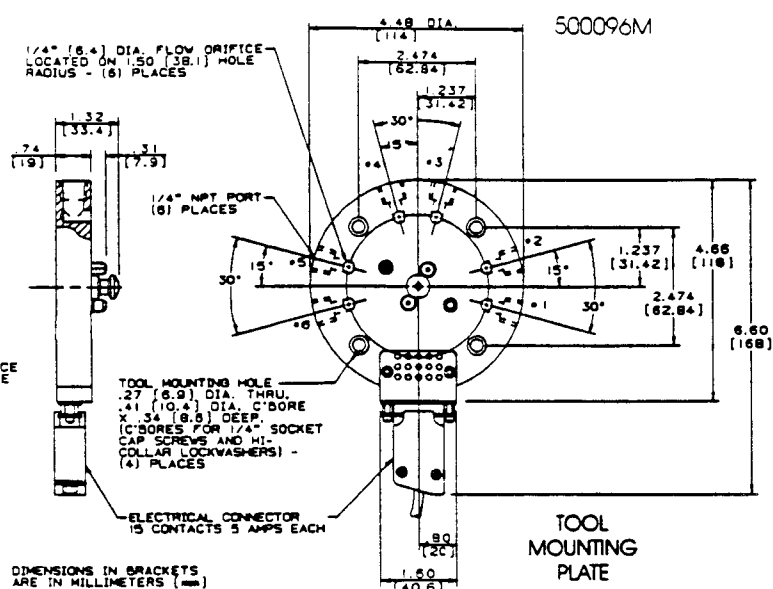
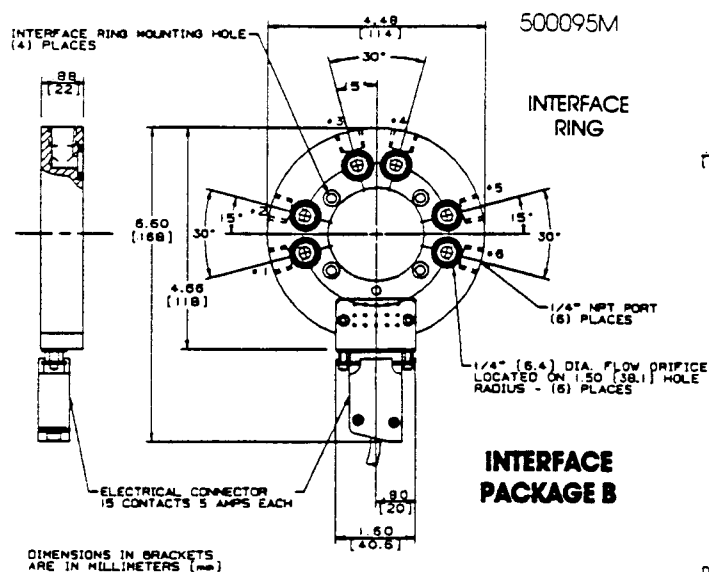
QUICK CHANGE BODY



500093M



QUICK CHANGE ADAPTORS



MODEL 50

The Model 50 Quick Change Adaptor has been designed for intermediate payload manufacturing applications. The 50-lb. payload capacity of the Model 50 allows a wide range of manufacturing and assembly tools to be utilized in a manufacturing environment. The design of the coupling mechanism, which distributes load forces evenly throughout the Quick Change Adaptor, allows the user to rapidly move from point to point without undue stress on the Quick Change Adaptor. When you're designing an interchangeable tooling application in a manufacturing environment, consider the rugged and dependable Model 50 Quick Change Adaptor.

ADAPTOR PLATE

ENGINEERING SPECIFICATIONS

Combined* Height: 2.25" (57.15mm)

Combined* Weight: 2.75 lbs.

Payload: 50 lbs. (23kg)

Moment: 600 in.-lbs.

(68N-M)

Represents combined height and weight of Quick Change assembly and Tool Mounting Plate when coupled.

Position
Repeatability: $\pm .001"$
(.025mm)

Material: Aluminum,
Tool Steel

Operating Pressure: 70 PSI (483kPa),
4-way valve

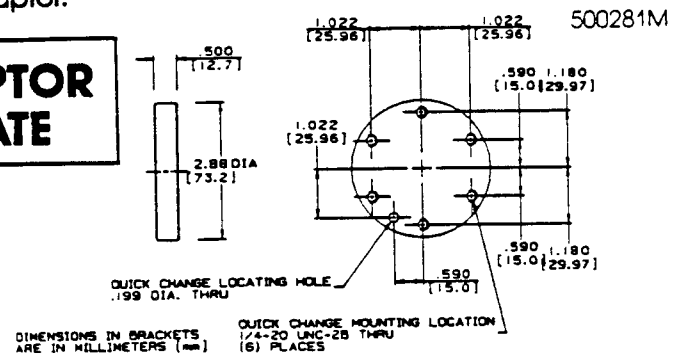
INTERFACE PACKAGES

Interface Package	Ports	Port Size (NPT)	Electrical Contacts	Rating
A	4	2 - 3/8" 2 - 1/4"	15	5 amps, 120V
AA	4	2 - 3/8" 2 - 1/4"	30	5 amps, 120V
B	6	1/4"	15	5 amps, 120V
C	2	10 - 32	15	5 amps, 120V

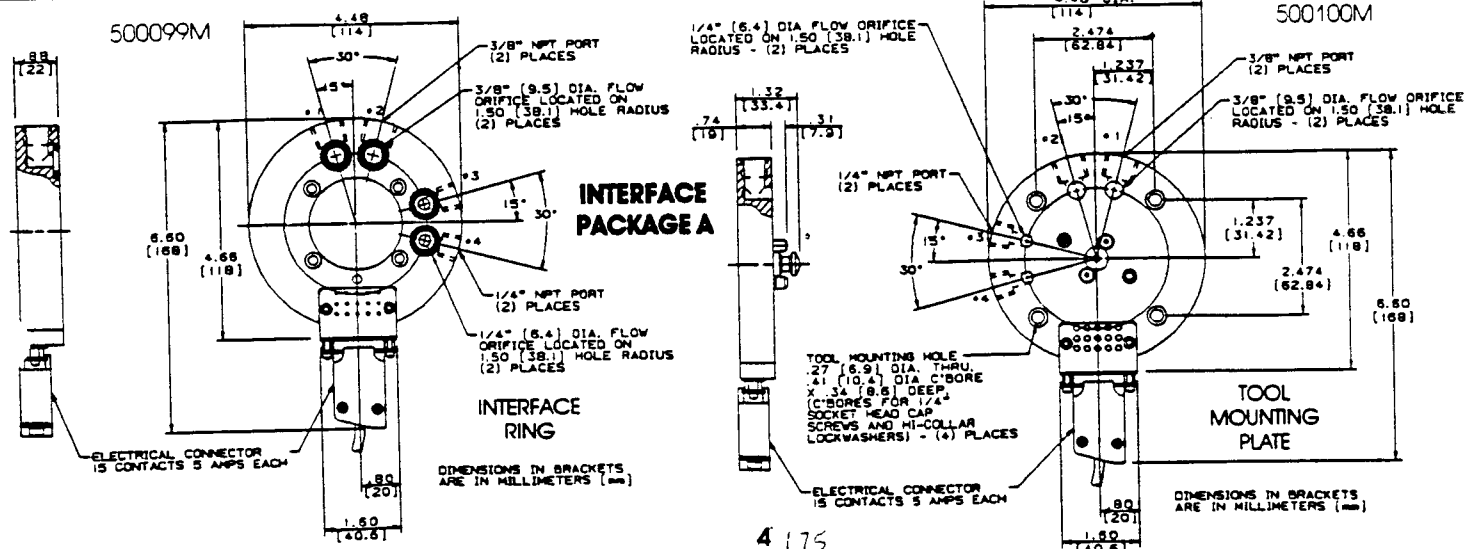
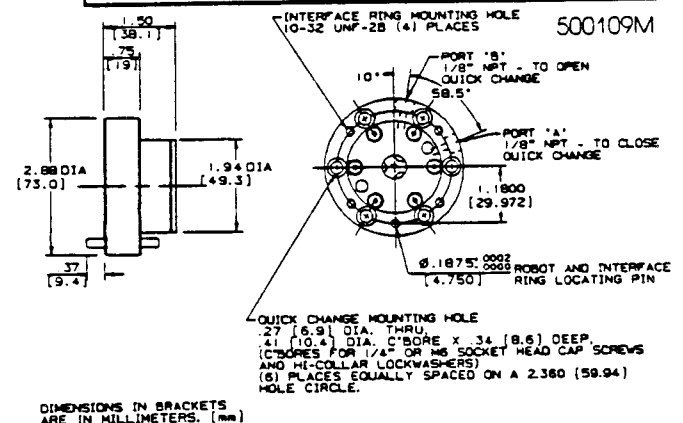
NOTE: EOA supplies at no additional charge 6 ft. (1.8M) of 15 conductor cable with each quick change assembly and 1 ft. (.3M) of 15 conductor cable with each Tool Mounting Plate.

4 Way valve and hose package to operate Quick Change is available as an option (includes 4 ft. (1.2M) valve control wire, pipe fittings, exhaust muffler, and 6 ft. (1.8M) of hose per port)

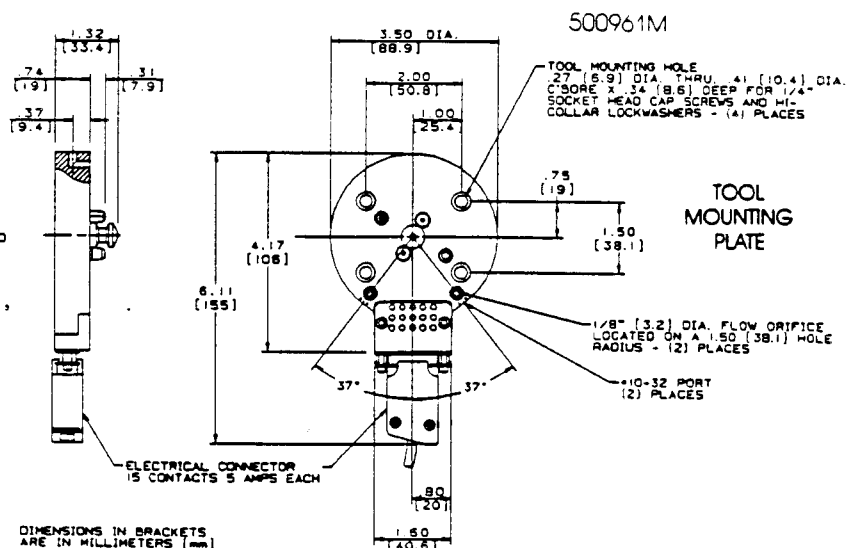
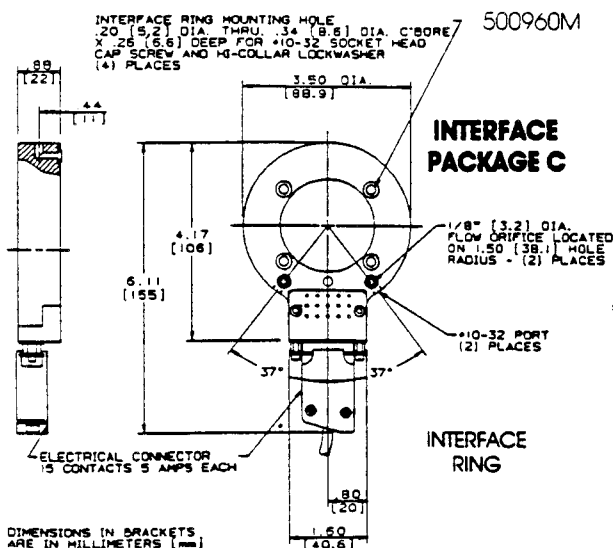
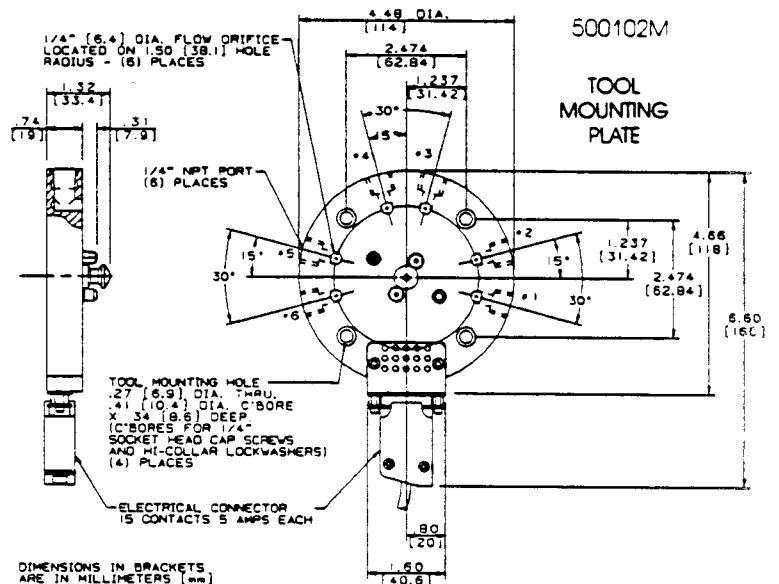
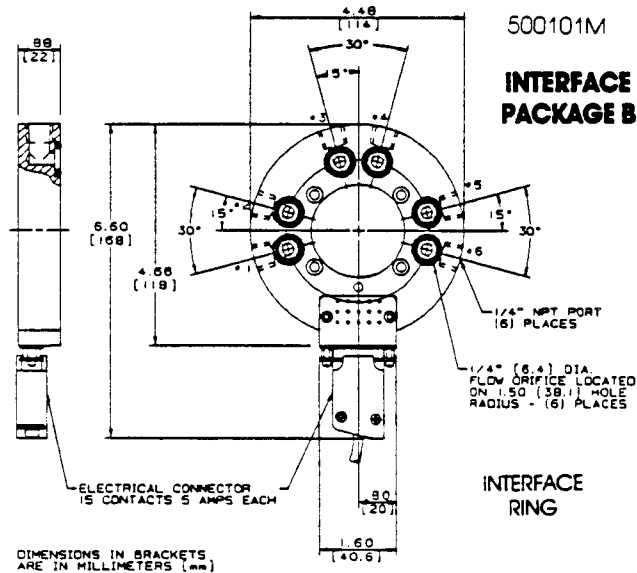
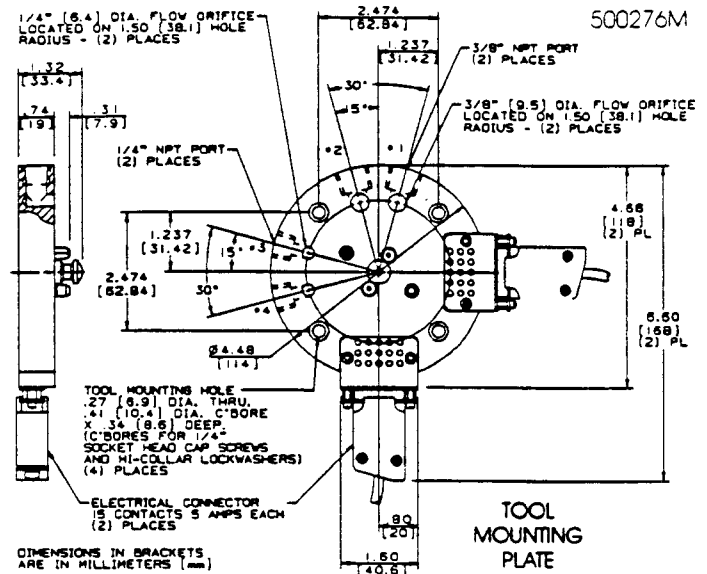
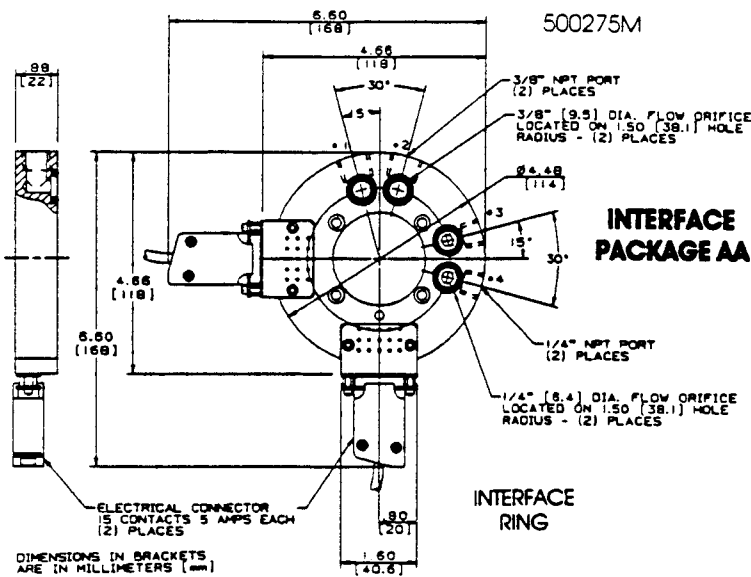
The Model 50 Series Quick Change Adaptors can be modified to operate in a Class 100 Clean Room Environment.



QUICK CHANGE BODY



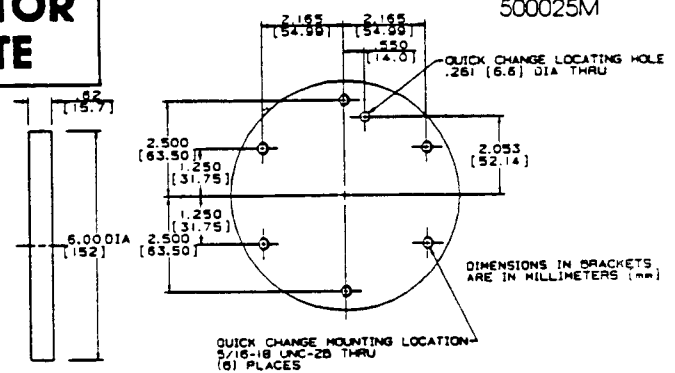
QUICK CHANGE ADAPTORS



MODEL 225

For heavier payload applications, EOA Systems offers the Model 225 Quick Change Adaptor designed to efficiently interchange heavy manufacturing tools. These tools, to operate properly, frequently require substantial pneumatic and electrical capabilities. The Model 225 is available with 1/2" ports and up to thirty-two electrical contacts to easily handle these tooling requirements. EOA Systems offers the Model 225 to allow the user maximum flexibility in tooling selection and implementation.

ADAPTOR PLATE

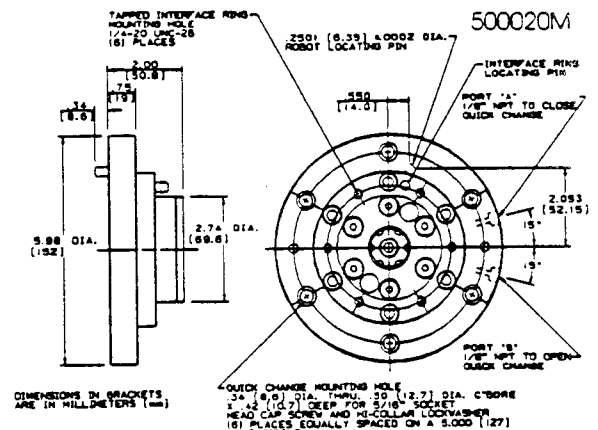


ENGINEERING SPECIFICATIONS

Combined* Length: 3.38" (85.85mm)
 Combined* Weight: 11.4 lbs. (5.2kg)
 Payload: 225 lbs. (102kg)
 Moment: 2,700 in.-lbs. (305N-M)
 Material: Aluminum, Tool Steel
 Operating Pressure: 70 PSI (483kPa), 4-way valve

* Represents combined height and weight of Quick Change assembly and Tool Mounting Plate when coupled.

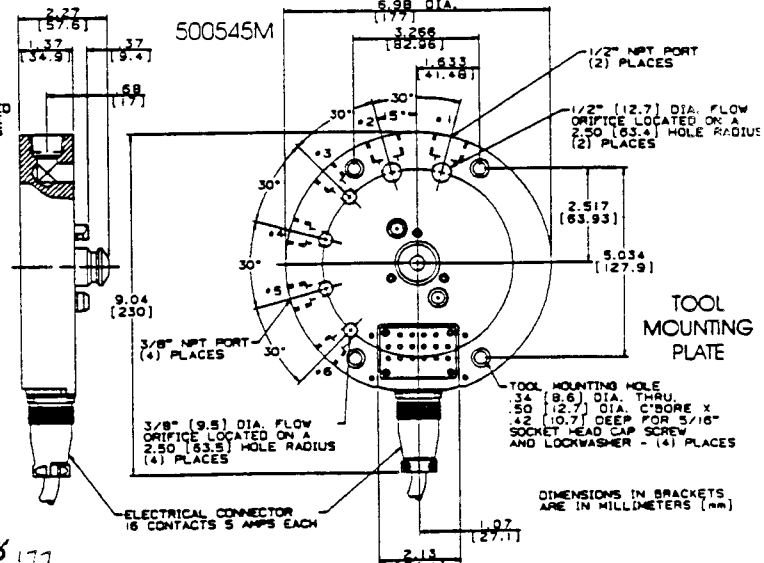
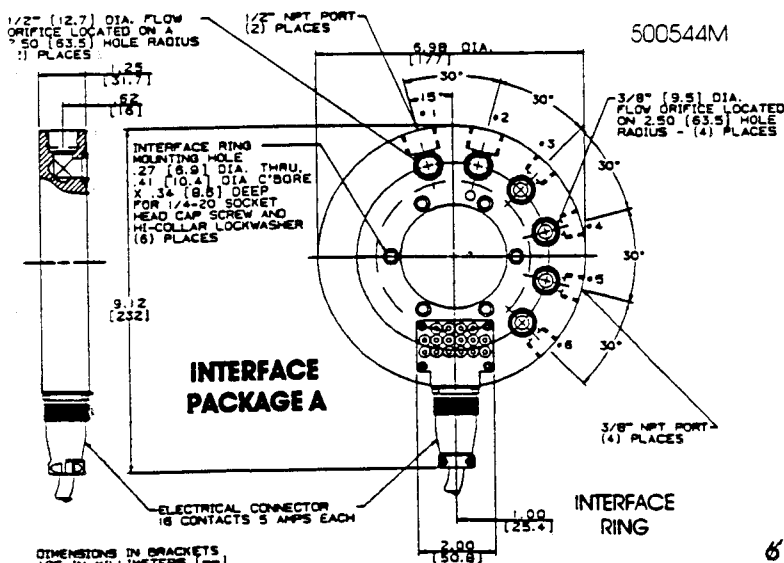
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INTERFACE PACKAGES

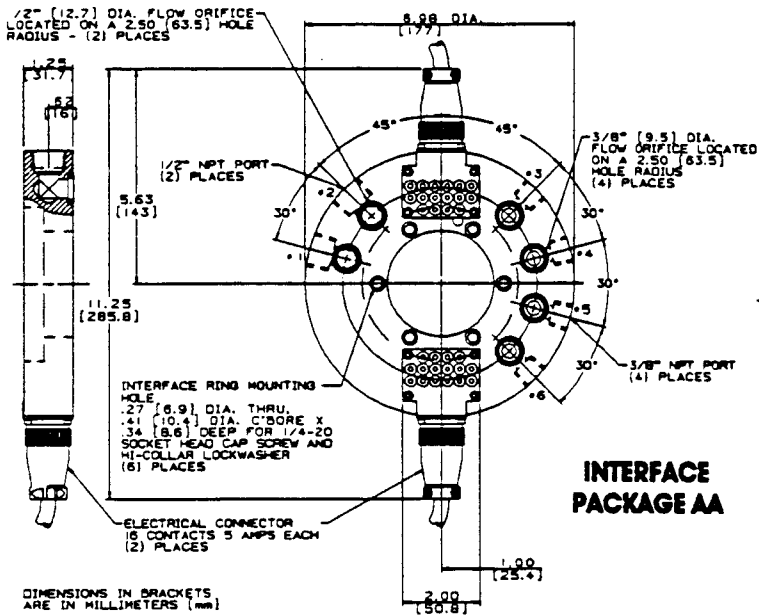
Interface Package	Fluid Ports	Air Ports	Port Size (NPT)	Electrical Contacts	Rating
A		6	2 - 1/2 4 - 3/8	16	5 amps, 120V
AA		6	2 - 1/2 4 - 3/8	32	5 amps, 120V
B	0	0	0	0	N/A

EOA can supply, as an option, 20 ft. (6M) of robot interface cable and 1 ft. (.3M) of tool interface cable.
 4 Way valve and hose package to operate Quick Change is available as an option (includes 4 ft. (1.2M) valve control wire, pipe fittings, exhaust muffler, and 6 ft. (1.8M) of hose per port)



QUICK CHANGE ADAPTORS

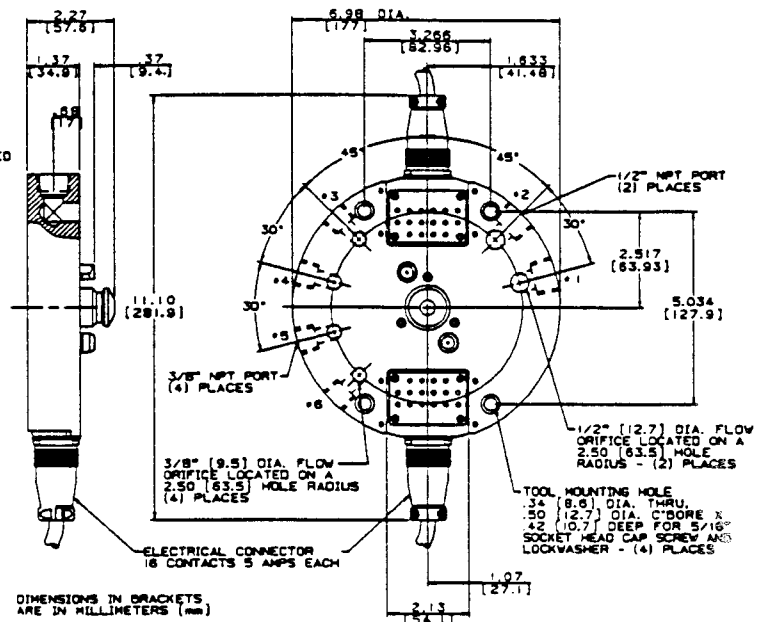
500548M



INTERFACE PACKAGE AA

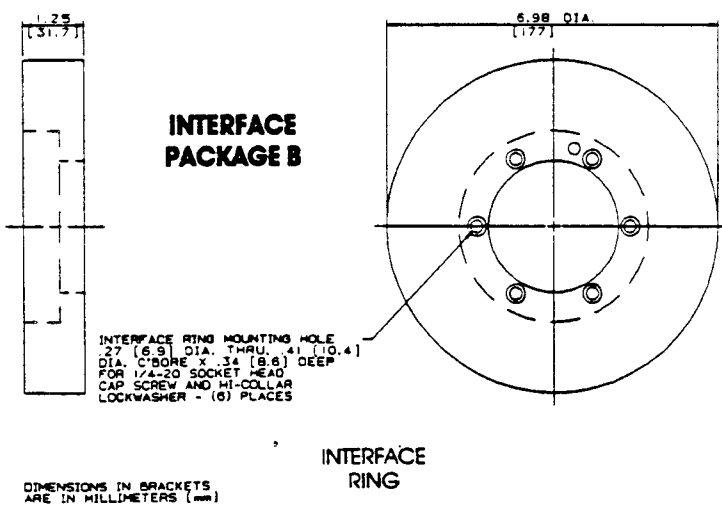
INTERFACE RING

500549M



TOOL MOUNTING PLATE

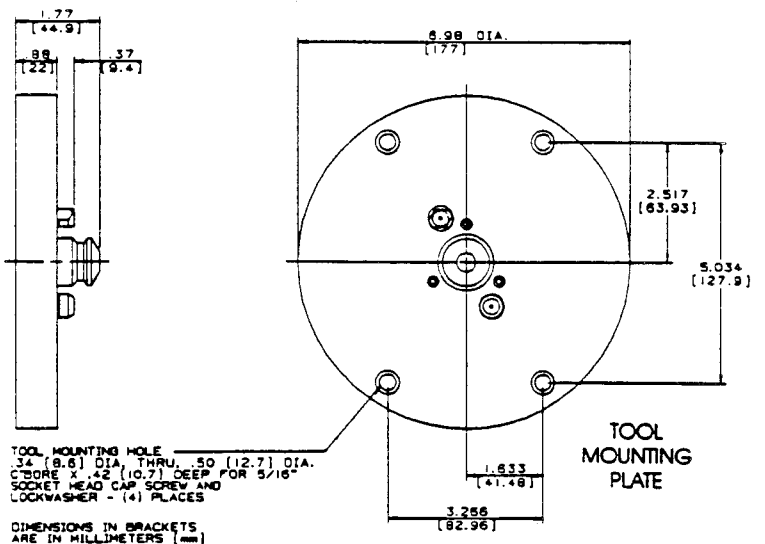
500071M



INTERFACE RING

INTERFACE PACKAGE B

500072M



TOOL MOUNTING PLATE

MODEL 300

EOA Systems has developed the Model 300 for heavy payload, high moment applications. The Model 300 is available to users configured for integral spot welding guns or other end of arm tools which exert high moments during operation. This unique Quick Change Adaptor can quick disconnect the 200 amp contacts needed in spot welding applications while also quick disconnecting all pneumatic, fluid, and low current connections to the integral spot welding gun. The capabilities of the Model 300 open many new horizons in robotic spot welding applications. Consider the Model 300 for all your high payload robot tooling applications.

ENGINEERING SPECIFICATIONS

Combined* Length: 3.38" (85.85mm)
Combined* Weight: 14.0 lbs.

Position
Repeatability: $\pm .001"$
(.025mm)

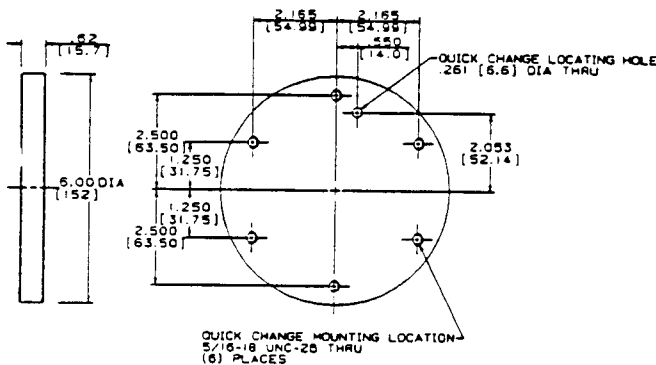
Payload: 300 lbs. (136kg)
Moment: 3,600 in.-lbs.
(407N-M)

Material: Aluminum,
Tool Steel

Operating Pressure: 70 PSI (483kPa),
4-way valve

* Represents combined height and weight of
Quick Change assembly and Tool Mounting Plate when coupled.

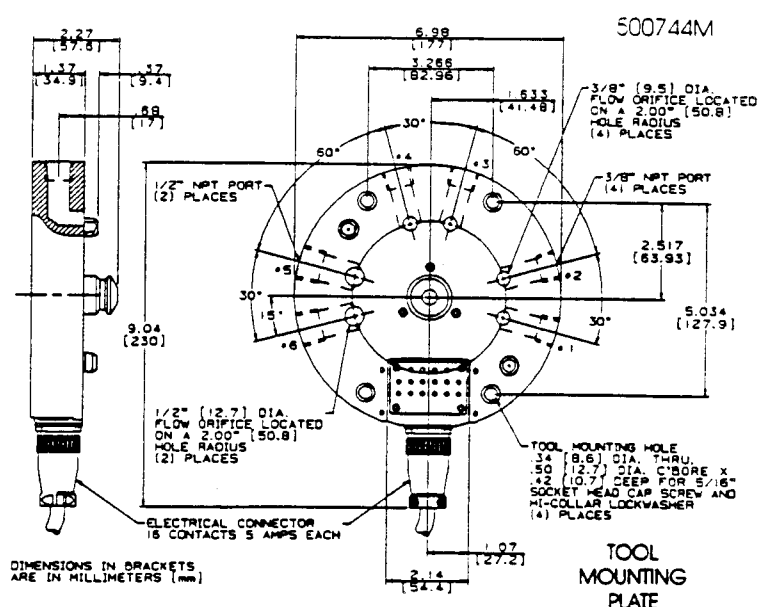
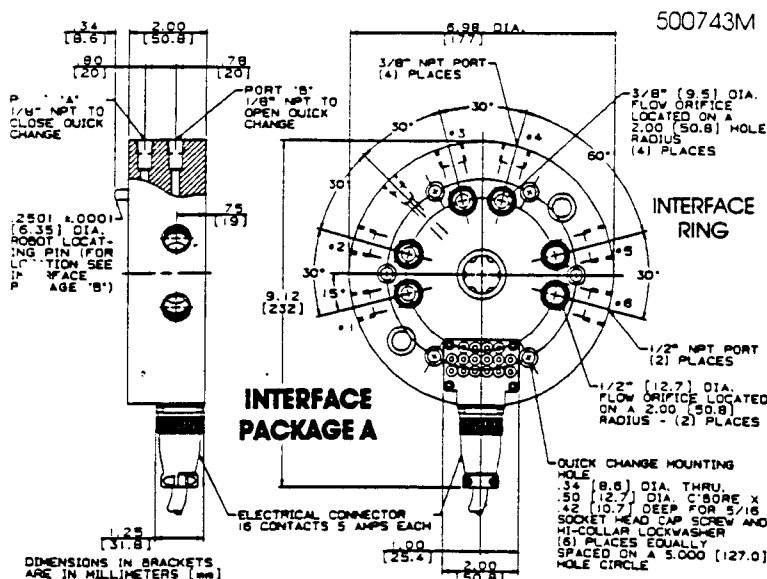
ADAPTOR PLATE



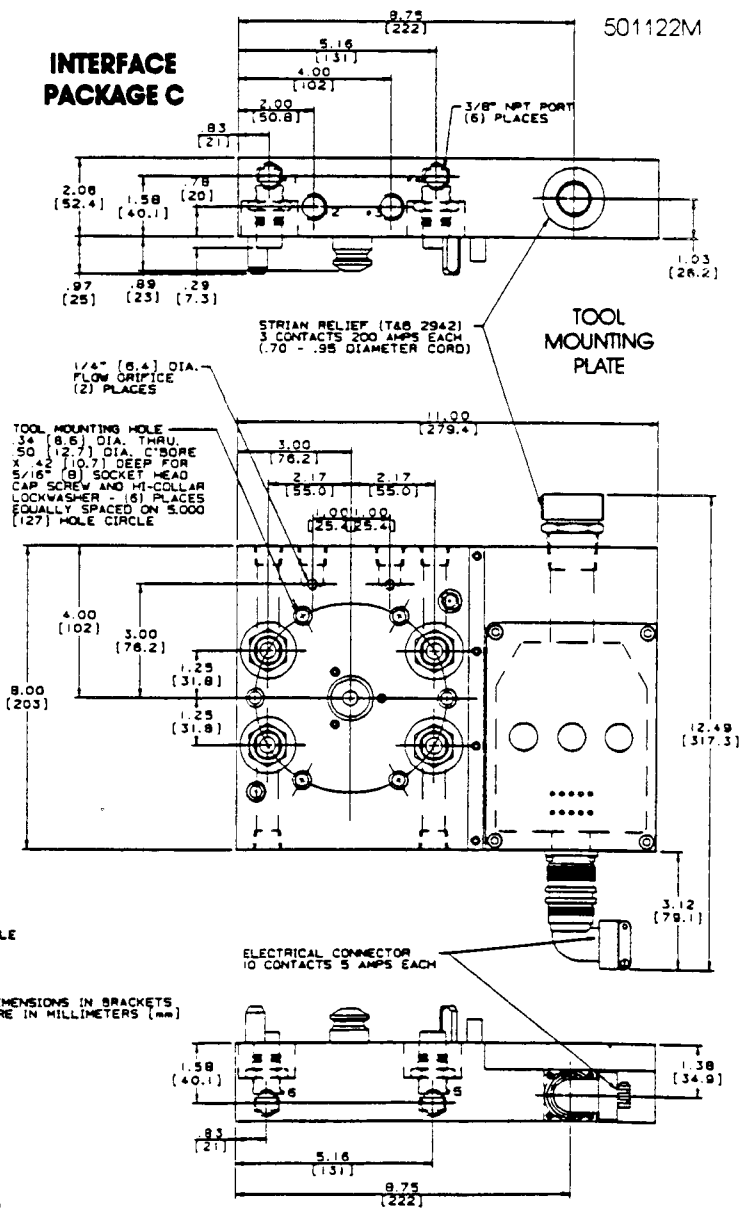
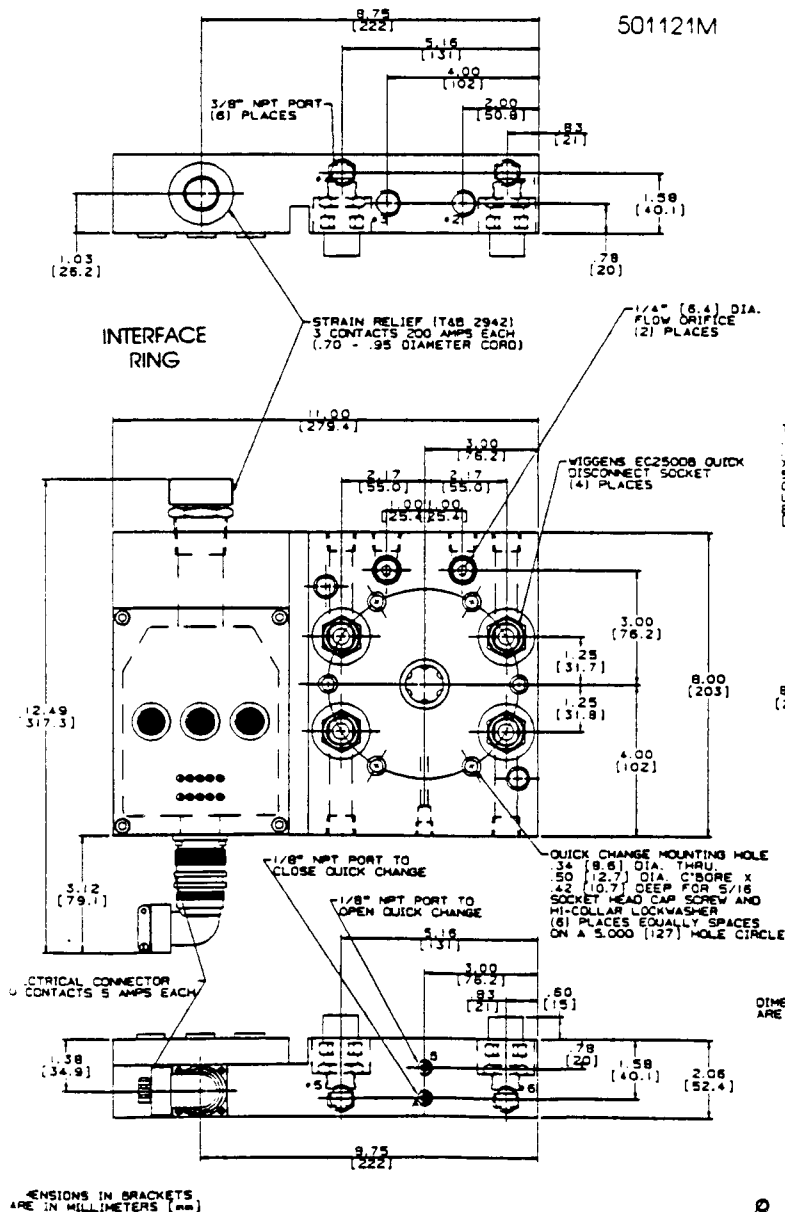
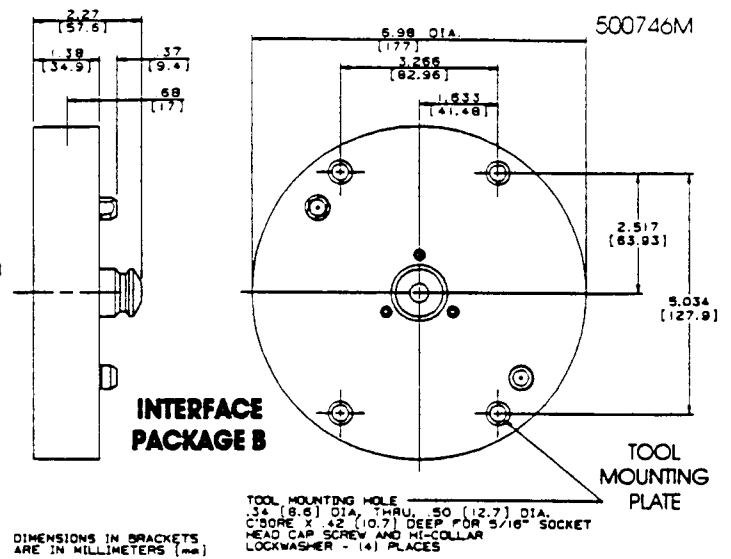
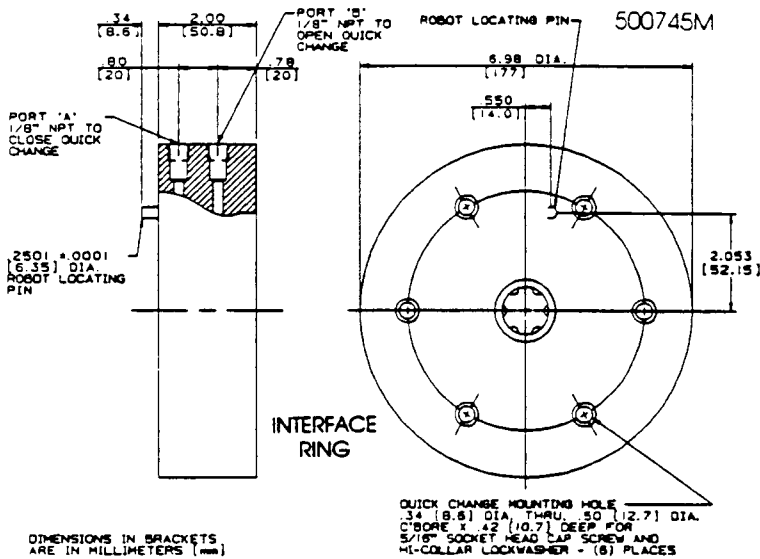
INTERFACE PACKAGES

Interface Package	Fluid Ports	Air Ports	Port Size (NPT)	Electrical Contacts	Rating
A		6	2 - 1/2 4 - 3/8	16	5 amps, 120V
B	0	0	0	0	N/A
C	4	2	6 - 3/8	10 3	5 amps, 120V 200 amps, 480 V

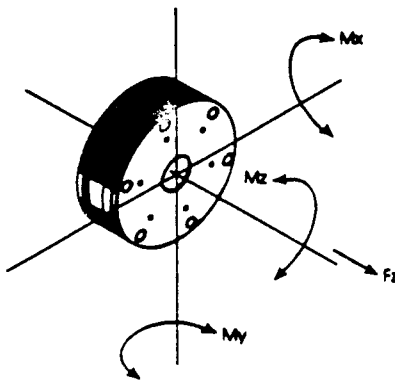
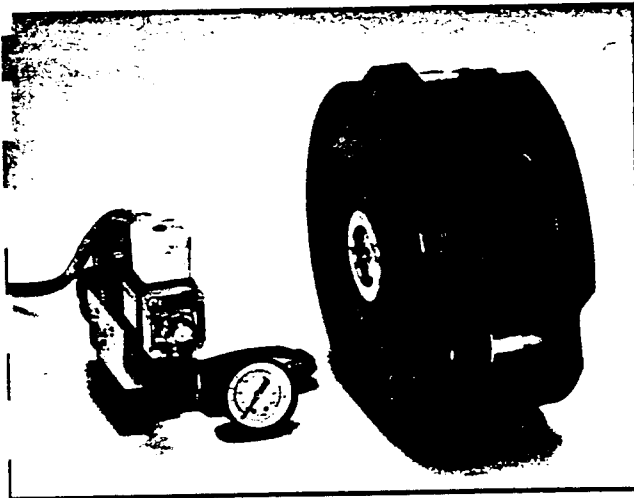
EOA can supply, as an option, 20 ft. (6M) of robot interface cable and 1 ft. (3M) of tool interface cable. 4 Way valve and hose package to operate Quick Change is available as an option (includes 4 ft. (1.2M) valve control wire, pipe fittings, exhaust muffler, and 6 ft. (1.8M) of hose per port)



QUICK CHANGE ADAPTORS



MULTICLUTCH BREAKAWAY SAFETY DEVICE



OVERVIEW

- User can set a trip point which is optimum for specific application requirements.
- MultiClutch automatically resets itself – greatly reducing time-consuming operator intervention.
- Keyed to reset itself in the same location repeatable to .001" (.025mm). Eliminates time-consuming recalibration of the tool.
- The most overtravel of any safety joint on the market.
- Rugged aluminum and steel construction enables MultiClutch to take repeated shocks.

The EOA MultiClutch Breakaway Device is a programmable end of arm tooling breakaway safety device which can automatically adjust breakaway sensitivity for different end effectors, velocities, and accelerations throughout the robot program. With MultiClutch the user is allowed up to 16 breakaway sensitivity settings (2 settings standard) which can be independently set depending on the requirements of the application. This variable sensitivity feature allows the user the flexibility to adjust MultiClutch breakaway sensitivity depending upon the likelihood of tooling damage at a particular point in the robot program. Furthermore, the variable sensitivity feature gives MultiClutch the ability to act as multiple clutches when quick changing multiple tools of varying weights and centers of gravity. MultiClutch will E-Stop the robot upon detection of the breakaway condition and is designed from aluminum and tool steel construction to withstand the rigors of the production environment.

HOW IT WORKS

- MultiClutch utilizes air pressure which is channeled in front of or behind a piston internal to the clutch. The piston serves to either assist or counteract the springs within MultiClutch. Thus, by varying the air pressure on the piston the user can vary the breakaway sensitivity of the springs in MultiClutch.
- MultiClutch has a multiple pressure regulating valve which has 2 sensitivity settings (up to 16 sensitivity settings are available) covering a range of air pressures from 5 to 150 PSI (34 to 1034 kPa). The user can use the 2 settings to select air pressures which allow the desired breakaway sensitivity depending on the moments exerted on the tooling in the particular application. When air pressure is applied to Port B the piston is counteracting the internal spring pressure which is operating the clutch in the low range of acceptable moments and forces. When air pressure is applied to Port A the piston is assisting the internal spring pressure which has the effect of increasing the allowable moments and forces into the high range.
- The 2 user adjusted settings on the multiple pressure regulating valve can be automatically activated using a single robot output. The effect is that the user can automatically vary, throughout the robot program, the desired breakaway sensitivity of MultiClutch.

HOW IT CAN REDUCE ROBOT DOWNTIME

- MultiClutch protects robot tooling and cell fixtures through its ability to breakaway and E-Stop the robot upon detection of an overload condition. MultiClutch will protect tooling and cell fixtures from collisions resulting from programming errors and misaligned work pieces. This insurance against damaging application specific robot tooling will substantially increase the confidence level and uptime of the robot cell.
- MultiClutch can automatically reset itself through the use of locating keys within MultiClutch. Following a breakaway condition, the operator simply maneuvers the robot away from the collision and when the load is off the tool, the clutch will automatically reset through the internal springs pulling the breakaway plate into the locating keys. **The clutch will reset itself in precisely the same location every time eliminating the need to re-program the robot. More importantly, maintenance does not need to be called to reset the clutch.**
- A variable sensitivity clutch allows the user to adjust the sensitivity throughout the robot program according to the application requirements. This gives the user greater flexibility to program faster motions with higher payloads without sacrificing breakaway sensitivity. The variable sensitivity MultiClutch compares very favorably with single setting clutches which must be manually set and re-set to the highest moment placed on the tool throughout the robot program. Single setting clutches force the user to sacrifice either robot acceleration or breakaway sensitivity.
- The ability of MultiClutch to vary breakaway sensitivity is especially useful when utilizing interchangeable tools of various weights and centers of gravity. Because MultiClutch can automatically vary breakaway sensitivity the user can set unique breakaway thresholds for each interchangeable tool used in the cell. Thus, MultiClutch can perform as many clutches in one.

WHY MULTICLUTCH CAN WITHSTAND THE MOST RIGOROUS PRODUCTION ENVIRONMENT

- All tool steel and aluminum construction provides the robust characteristics to withstand repeated breakaway conditions.
- All tool steel and aluminum construction allows zero deflection up to breakaway.
- Simplicity of the enclosed spring assisted piston design requires no maintenance and is virtually problem free.
- No exposed springs, wires, or switches.

MULTICLUTCH

ENGINEERING SPECIFICATIONS

MULTICLUTCH 50

Moment Rating: 0 to 1,000 in.-lbs. (0 to 113 N-m)

Force Rating: 0 to 780 lbs. (0 to 354 kg)

Weight: 5 lbs. (2.3 kg)

Applications: Arc Welding, Material Handling, Material Removal

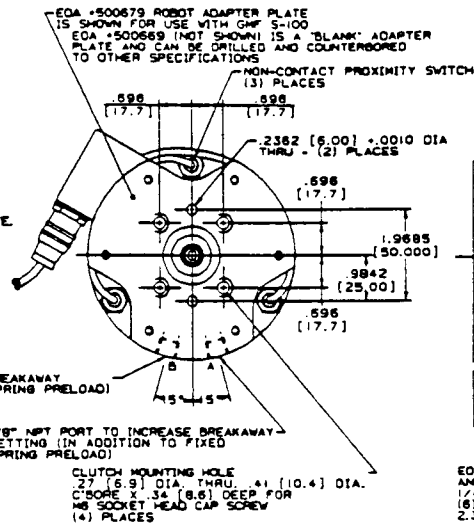
NOTES:

- 2.43 WIDTH SHOWN FOR EDA #500679 ADAPTER PLATE. OVERALL WIDTH IS 2.31 [58.7] WHEN EDA #500669 ADAPTER PLATE IS USED.

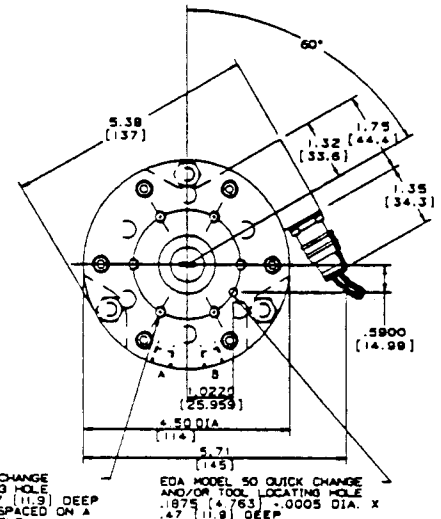
1/8" NPT PORT TO DECREASE BREAKAWAY SETTING (OFFSETTING FIXED SPRING PRELOAD)

1/8" NPT PORT TO INCREASE BREAKAWAY SETTING (IN ADDITION TO FIXED SPRING PRELOAD)

DIMENSIONS IN BRACKETS ARE IN MILLIMETERS (mm)



500664M



ENGINEERING SPECIFICATIONS

MULTICLUTCH 300

Moment Rating: 0 to 8,100 in.-lbs. (0 to 915 N-m)

Force Rating: 0 to 3,100 lbs. (0 to 1400 kg)

Weight: 17 lbs. (7.7 kg)

Applications: Spot Welding, Palletizing, Material Handling

EDA MODEL 3225S AND 300 QUICK CHANGE AND/OR TOOL MOUNTING HOLE 1/4-20 UNC-2B X .62 [15.7] DEEP (6) PLACES EQUALLY SPACED ON A 5.000 [127] HOLE CIRCLE

CLUTCH MOUNTING HOLE .34 [8.6] DIA. THRU. .42 [10.7] DEEP FOR 5/16" SOCKET HEAD CAP SCREW AND HI-COLLAR LOCKWASHER - (6) PLACES EQUALLY SPACED ON A 5.000 [127] HOLE CIRCLE

NON-CONTACT PROXIMITY SWITCH (3) PLACES

CLUTCH MOUNTING HOLE .41 [10.4] DIA. THRU. .42 [10.7] DEEP FOR 5/16" SOCKET HEAD CAP SCREW AND HI-COLLAR LOCKWASHER - (6) PLACES EQUALLY SPACED ON A 5.000 [127] HOLE CIRCLE

CLUTCH MOUNTING HOLE .41 [10.4] DIA. THRU. .42 [10.7] DEEP FOR 5/16" SOCKET HEAD CAP SCREW AND HI-COLLAR LOCKWASHER - (6) PLACES EQUALLY SPACED ON A 5.000 [127] HOLE CIRCLE

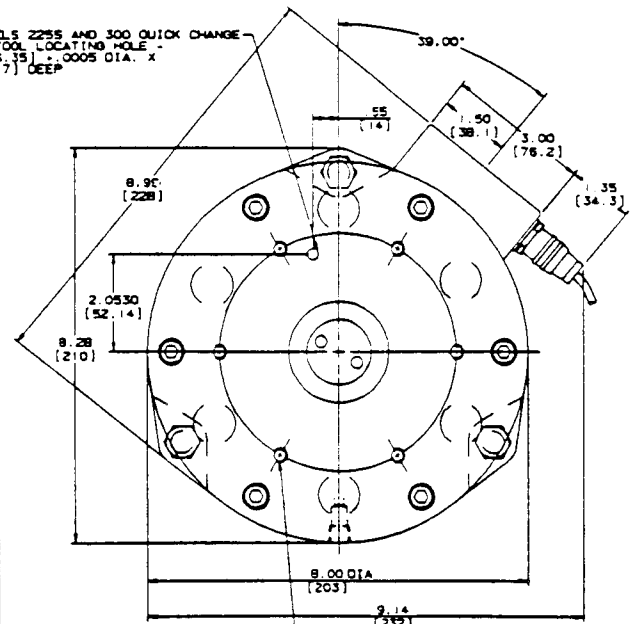
1/8" NPT PORT TO INCREASE BREAKAWAY SETTING (IN ADDITION TO FIXED SPRING PRELOAD)

1/8" NPT PORT TO DECREASE BREAKAWAY SETTING (OFFSETTING FIXED SPRING PRELOAD)

EDA #501182 ROBOT ADAPTER PLATE IS SHOWN FOR USE WITH THE FOLLOWING: CINCINNATI MILACRON 778 AND 785, GMF S-360, S-400 NO S-420 #500906 (NOT SHOWN) IS "BLANK" ADAPTER PLATE AND CAN BE DRILLED AND COUNTERBORED TO OTHER SPECIFICATIONS

DIMENSIONS IN BRACKETS ARE IN MILLIMETERS (mm)

500521M



Aerospace Robotic Manufacturing System

EOA Systems has developed the Aerospace Robotic Manufacturing System (ARMS) as a highly reprogrammable robotic end effector system designed especially for Aerospace applications. This sophisticated turnkey system combines precise micro processor control with sturdy, production ready construction to perform the most demanding aerospace manufacturing applications. The system components include: CNC AeroDrill with Control Pre-Processor, CNC AeroRouter, CNC AeroQuick Change Adaptor, and Two Station Tool Rack.

CNC AeroDrill with Control Pre-Processor

The CNC AeroDrill is a reprogrammable, drilling end effector especially designed to drill the close tolerance holes typically found in aerospace drilling applications. The CNC AeroDrill attains its reprogrammable nature and precise micro processor control from the EOA Systems Control Pre-Processor. The Control Pre-Processor provides the user with the flexibility to program multiple drilling parameters for every hole drilled. In addition, the CNC AeroDrill has the ability to automatically interchange multiple drill bits which allow the user to use one end effector to drill many variably defined holes. The ability to freely reprogram drilling parameters as well as automatically interchange drill bits creates a drilling end effector with true CNC capabilities.

CNC AeroRouter

The EOA CNC AeroRouter is truly a revolutionary manufacturing tool designed for routing aircraft material. The CNC AeroRouter is revolutionary because it is the first variable speed, high horsepower, high RPM router which can automatically change cutters. As important, the tool does not use any coolant lines, which greatly simplifies installation. The user can use the CNC AeroRouter as either a freehand tool or use the 1.5" (38.1mm) of axial travel when riding a template. Because it uses the same amplifier and control as the CNC AeroDrill, the CNC AeroRouter can be added to a drill cell at a low incremental cost. Using the CNC AeroRouter's ability to automatically change speeds and cutters, the user can now route a wide variety of parts within a single robot cell.

CNC AeroQuick Change Adaptor

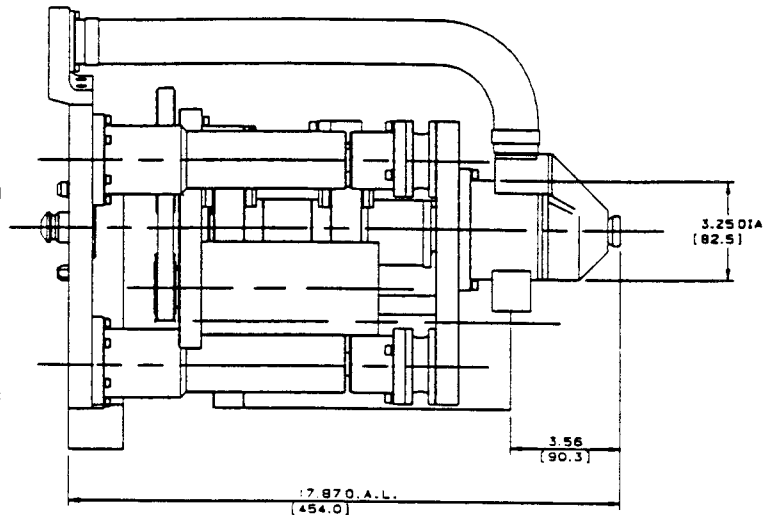
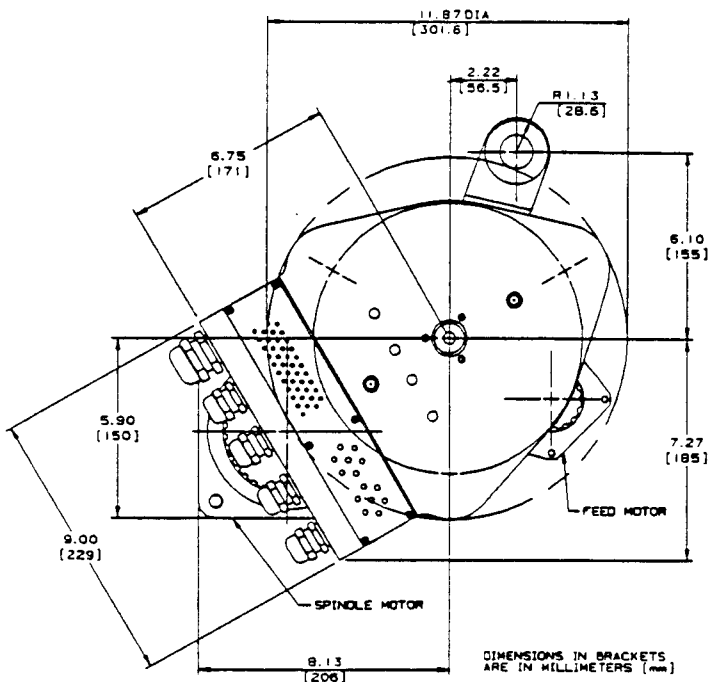
The CNC AeroQuick Change Adaptor is the tool which attaches to the robot wrist and interchanges the end effectors within ARMS. The EOA Quick Change is constructed from rugged tool steel and aluminum for years of excellent performance. The low profile of the CNC AeroQuick Change Adaptor minimizes tool point deflection which insures more repeatable robotic operations.

Two Station Tool Rack

The final component of ARMS is the two station tool rack capable of holding two end effectors and 8 interchangeable drill bit assemblies. The tool rack features a Blanchard ground steel surface which is easily expandable to accommodate the user's exact requirements. EOA Systems offer the tool rack as an important turnkey item in ARMS which will eliminate the need for the user to be concerned with proper fixturing of end effectors and associated interchangeable drill bit assemblies.

CNC AERODRILL

501232M



ENGINEERING SPECIFICATIONS

RPM Range of Spindle: 0 to 13,000 rpm (the user can select the optimum torque and spindle speed depending on the material drilled)

Spindle HP: 4.56

Drill bit thrust: 0 to 450

Feed: .0001" (.0025mm) to .1" (.254mm) per revolution

Weight: 75 lbs. (34.09kg)

Length: 16.87" (428.69mm) without compliance.

17.87" (453.89mm) with compliance.

Lateral Compliance: .1" (.254mm) of travel

Drill to depth tolerance: $\pm .001$ " (.025mm)

Drill stroke: 1.5" (38.1mm)

Cage accuracy: .0005" (.012mm)

Bit size range: .098" (2.48mm) to .500" (12.7mm)

Rapid traverse: 1.5 SEC. (Rapid traverse is the elapsed time for the spindle to travel the entire 1.5" stroke and back to home)

PROGRAMMABLE FEATURES

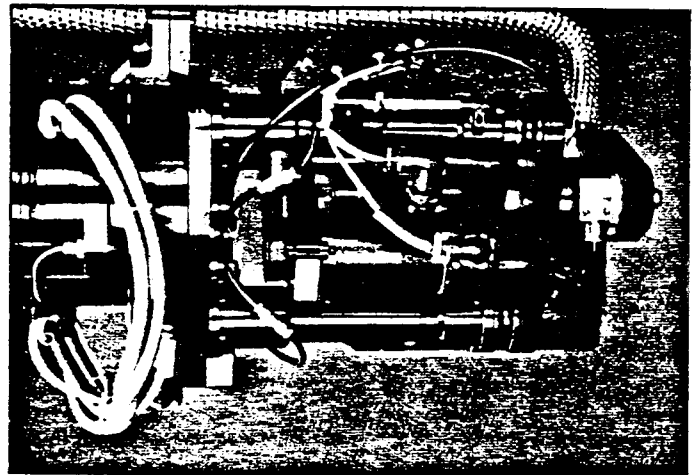
- Program a unique spindle speed and feedrate for each bit in the cell
- Change spindle speed and feedrate at programmed depths
- Change spindle speed and feedrate upon encountering different materials
- Drill to a programmed depth
- Program dull/broken bit thresholds
- Program peck drill cycle for any stroke and dwell time
- 29 other parameters can be programmed for each drill bit
- Unlimited number of drill bits can be used in cell

CONTROL PRE-PROCESSOR FEATURES

- Dimensions of 24"x24"x72"
- Communicates with the robot or cell controller over RS-232 or 24vdc I/O
- Keyboard and screen remote from cabinet
- Automatic calibration of tip of bit and countersink. Do not need to pre-set cutters in tool crib.
- Automatic diagnostics of drill operation
- Easy full sentence programming of all parameters
- User can program control pre-processor to control other end effectors

MECHANICAL FEATURES AND OPTIONS

- Automatic changeout of drill bits
- Sensors to detect part, fixture, and end effector movement
- Designed for use with the EOA CNC AeroQuick Change Adaptor
- Designed for drilling with or without a drill template
- Optional through bit coolant
- Optional Venturi tube cold air bit cooling
- Optional vacuum brackets and shroud to collect composite dust
- Optional 100' cables between CNC AeroDrill and control pre-processor
- Optional transformers built into control pre-processor



CNC AEROROUTER

ENGINEERING SPECIFICATIONS:

RPM Range of Spindle: 0 to 19,500

Spindle HP: 4.56 (higher HP motors available)

Weight: 85 lbs. (38.68Kg)

Length: 17.37" (441.18mm)

I/O Requirements: 4 input and 10 output relays

No liquid or forced air coolant used, which simplifies installation and operation.

MECHANICAL FEATURES AND OPTIONS:

- Automatic change out of cutters and vacuum shroud
- Slide mechanism with 1.5" (38.10mm) of travel perpendicular to the template to keep a constant programmed force on the template
- Optional vacuum brackets and shroud to collect composite dust
- Optional "C" shape configuration

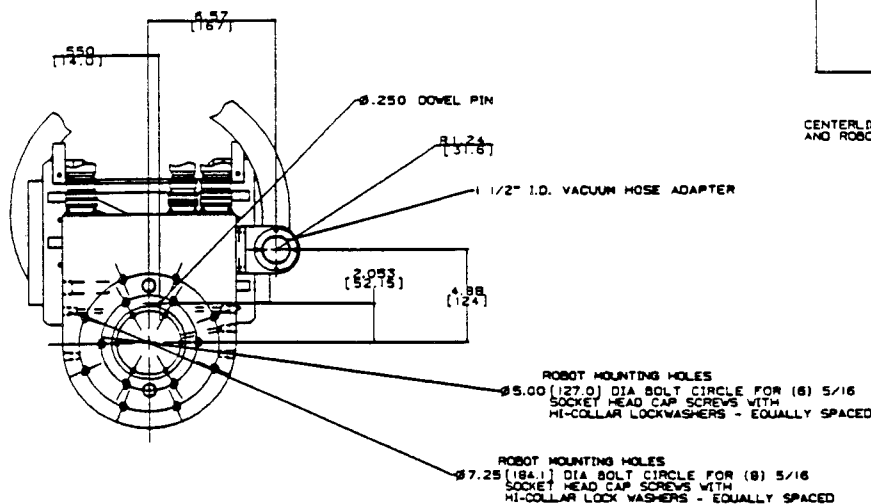
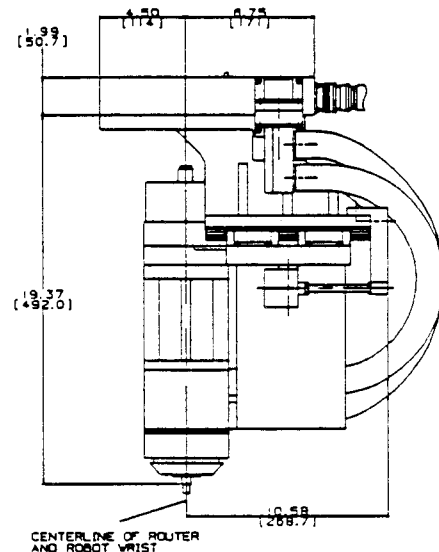
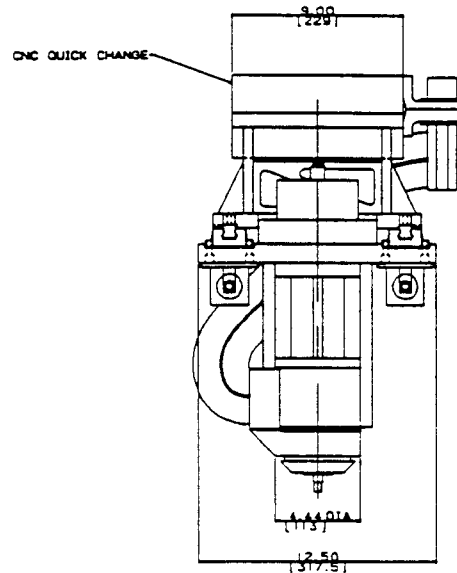
CONTROL PRE-PROCESSOR FEATURES:

- Dimensions of 12"x28"x40"
- Control pre-processor contains the amplifiers, relays, and safety switches
- Program router speeds and functions through robot control over serial link
- Change spindle speed while routing

OPTIONS:

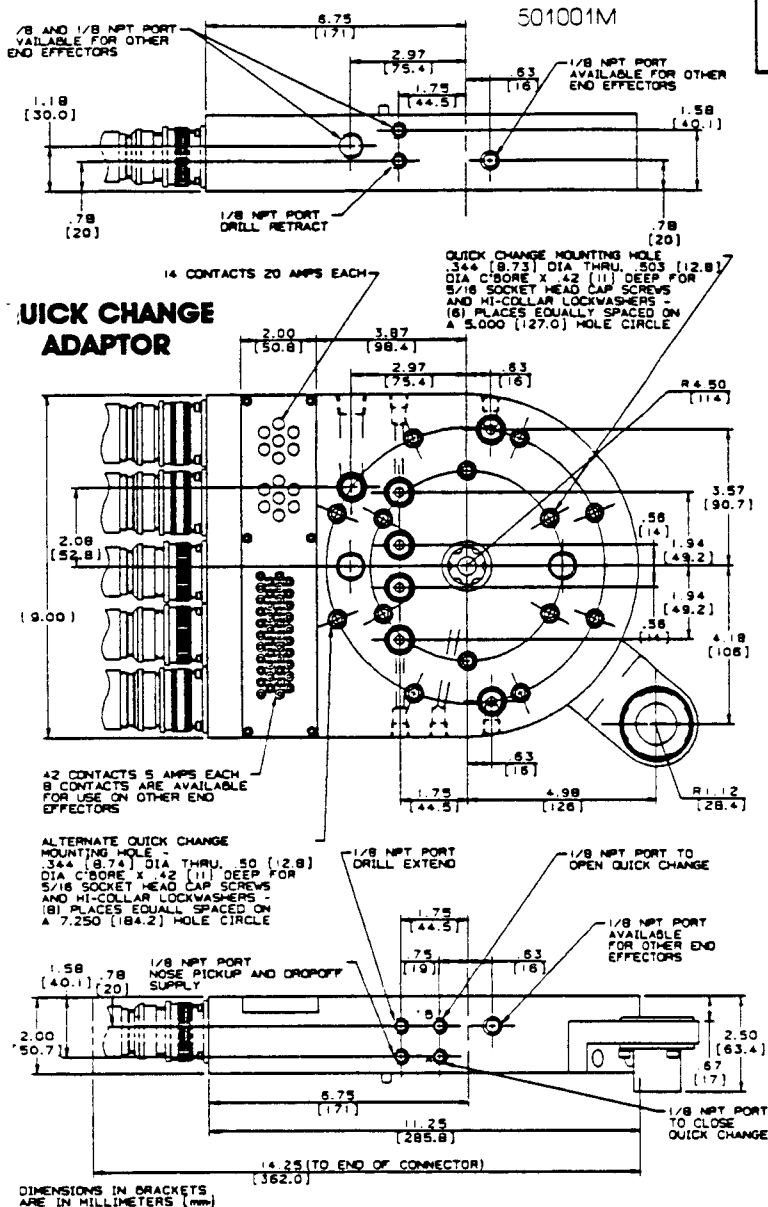
- Venturi tube cold air cooling of bit
- Tool rack for fixturing routers and interchangeable cutter assemblies

501325M



DIMENSIONS IN BRACKETS ARE IN MILLIMETERS (mm)

CNC AEROQUICK CHANGE ADAPTOR



ENGINEERING SPECIFICATIONS

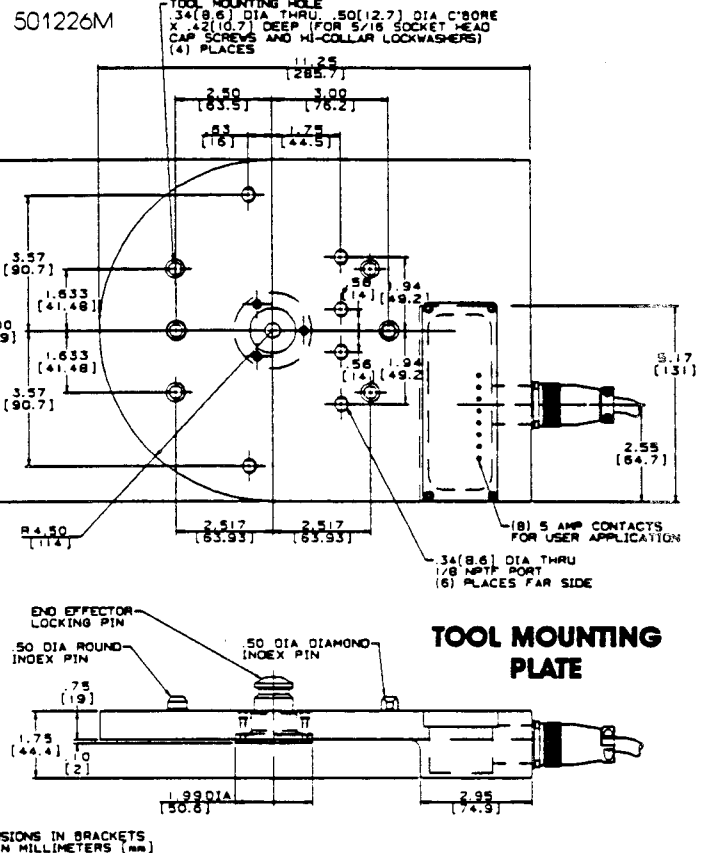
Weight: 15 lbs. (6.81kg)

Ports: 5 1/8" NPT ports (3 available to user for other end effectors)

1 3/8" NPT port (available to user for other end effectors)

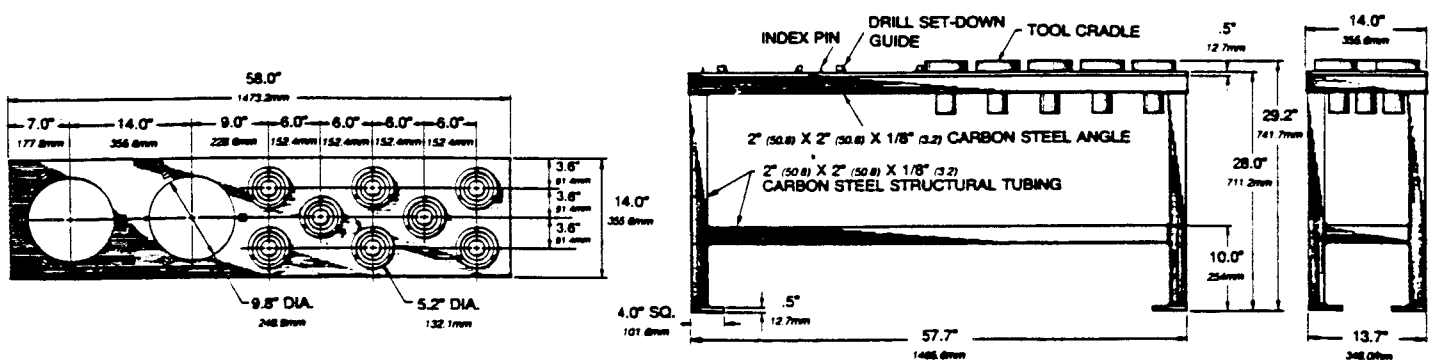
Contacts: 14 20amp contacts

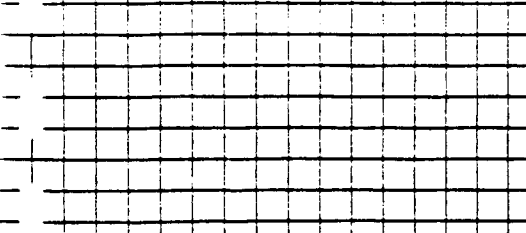
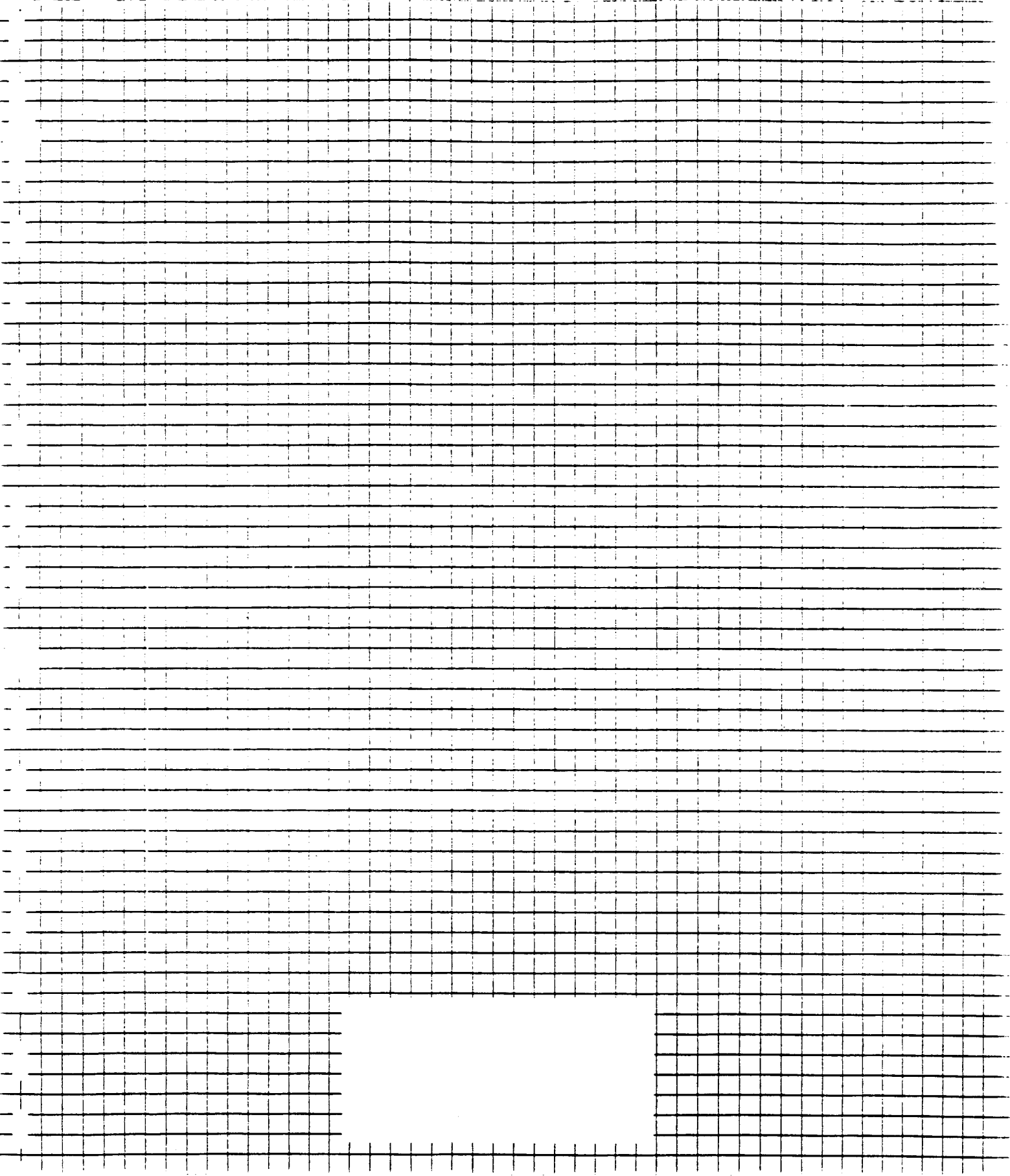
42 5amp contacts (8 available to user for other end effectors)



Aerospace Robotic
Manufacturing System

TWO STATION TOOL RACK

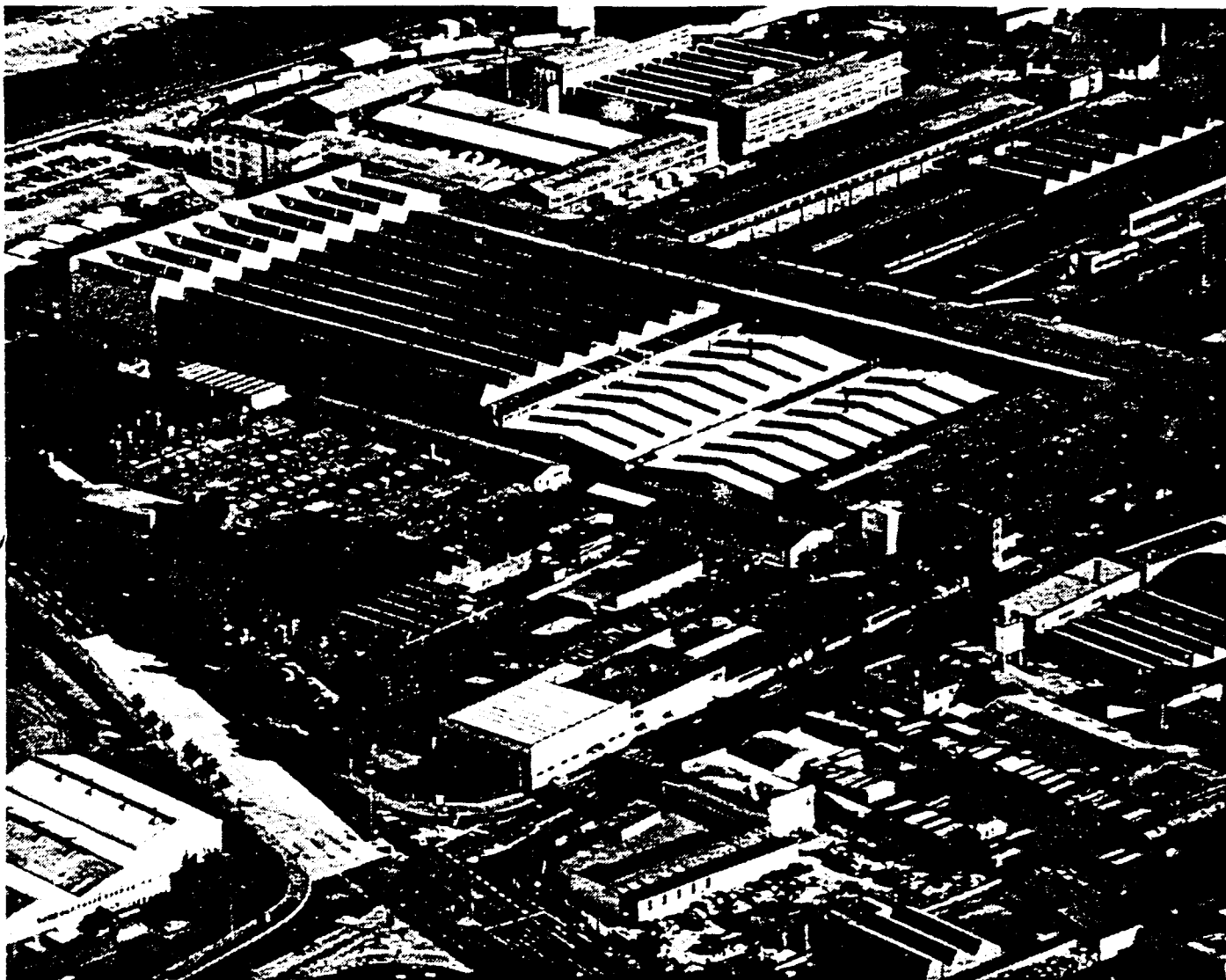




EOA SYSTEMS, INC.
15054 Beltway Drive • Dallas, Texas 75244 • Telephone: 214/458-9886 • FAX: 214/404-9338



FIBRO INC.



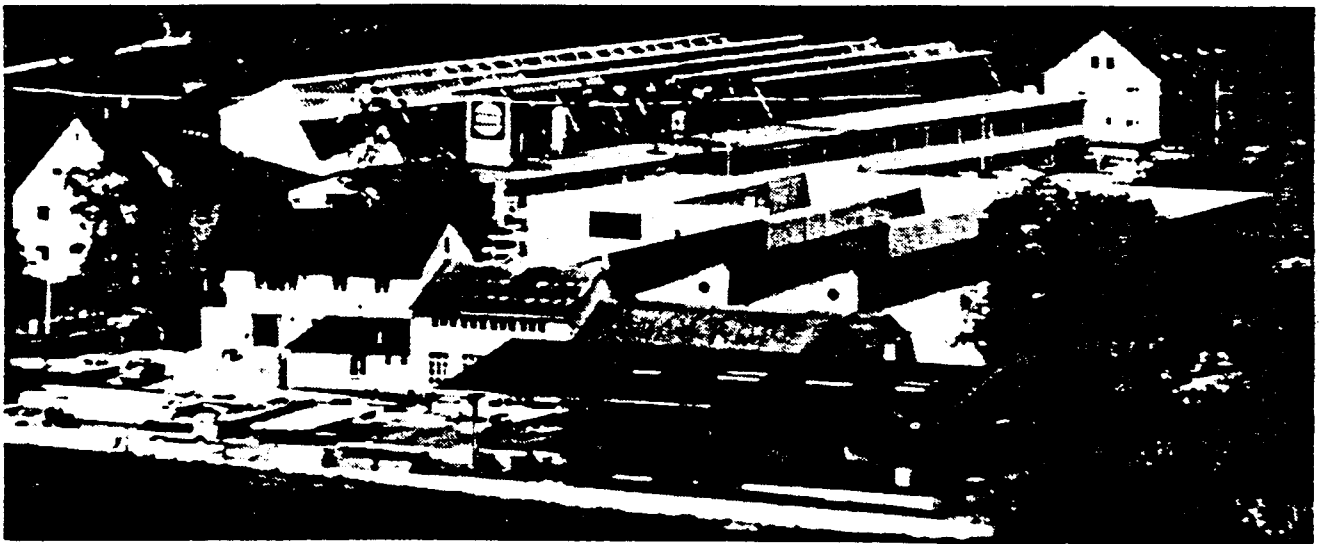
Lápplé Heilbronn — Automotive Parts



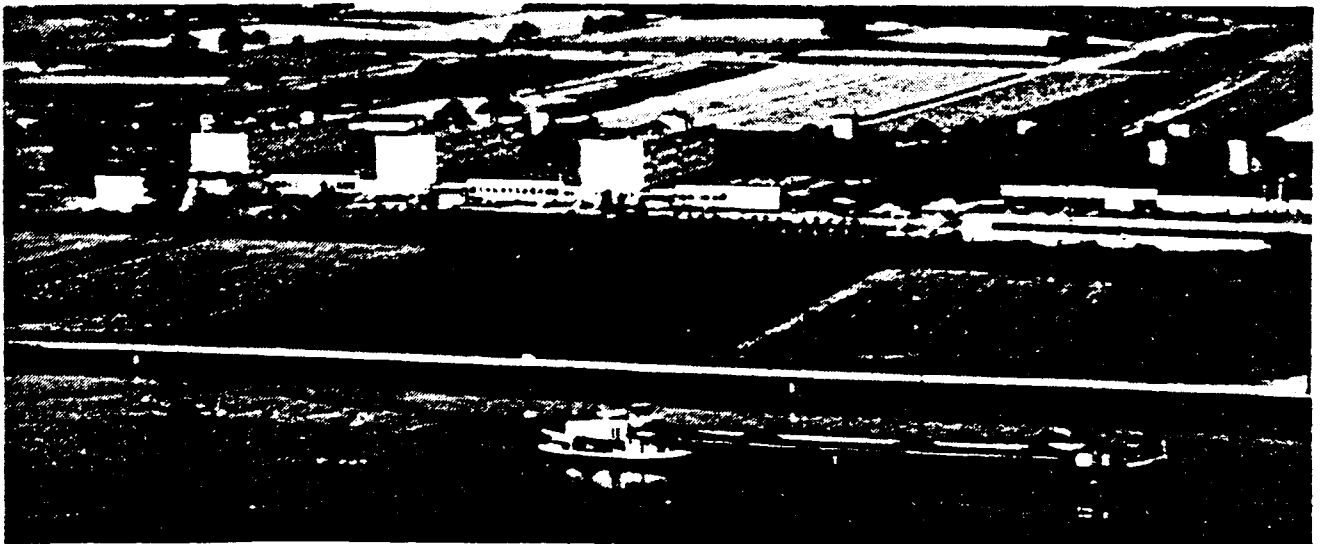
FIBRO INC.



Fibro Inc. Rockford, Illinois USA — Assembly, Engineering and Service



Fibro GmbH Weinsberg — Index and NC Tables



Fibro GmbH Hassmersheim — Modular Robotics



August Läßle, the
Founder of the Company



1885-1968

"Resting means falling behind." This maxim, under which August Läßle started his own operation in a small workshop in West Germany, still applies at FIBRO/Läßle.

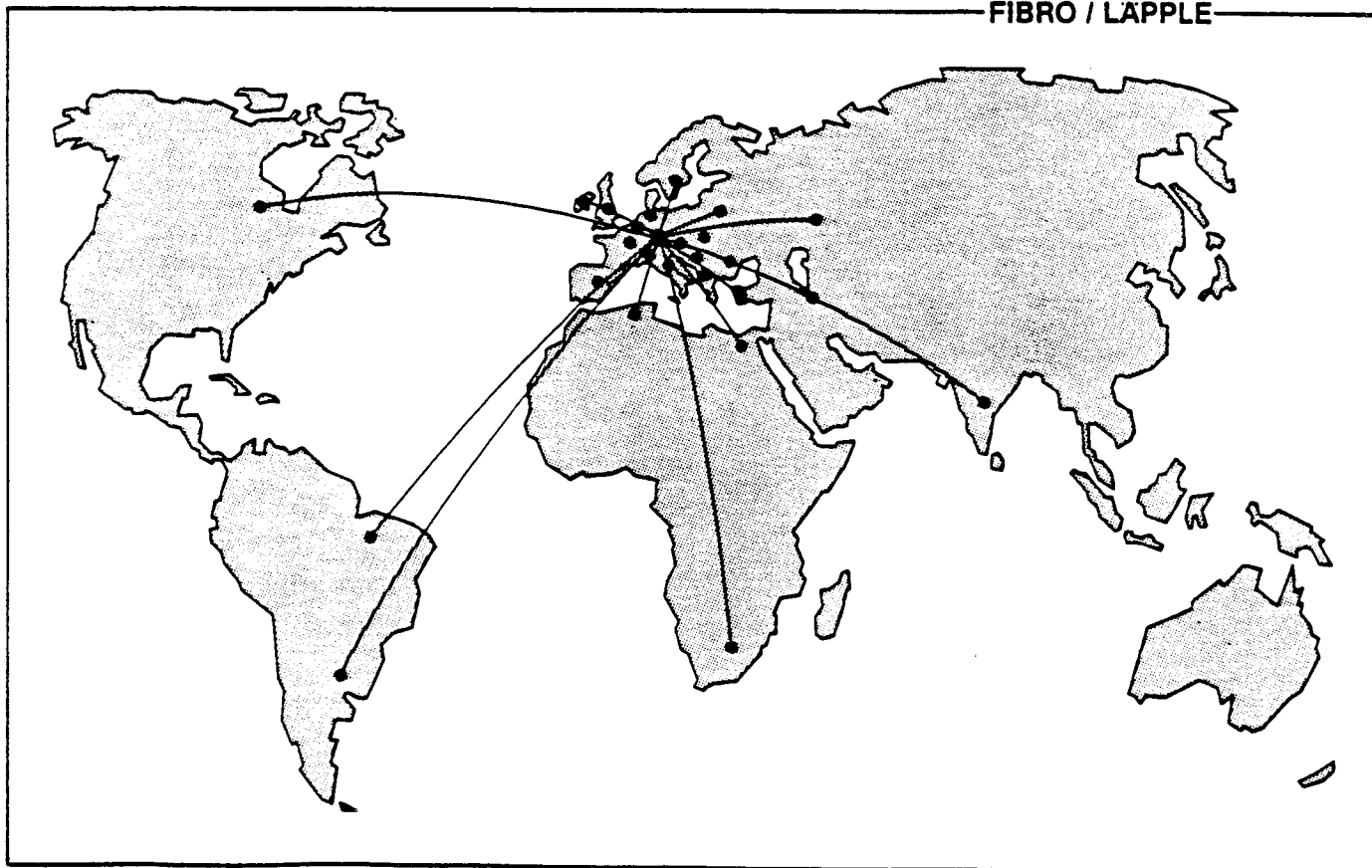
From the very beginning, the company has dealt with the manufacture of car body tools and dies, as well as the production of sheet metal pressings. Keeping pace with the latest technical developments while maintaining the highest standard of quality is the company's principal objective.

In 1950 the foundation of the new plant was laid in a Heilbronn meadow surrounded by grain fields. This was the start of the company's rapid expansion.

Up-to-date machine tools and outstanding expertise have made the master craftsman shop a large-scale contract toolroom, press shop and automation house with factories in world-wide locations.

Skilled craftsmanship is still an indispensable part of the precision work required for the finishing operations of automatic toolmaking. The experience gained in practice is passed directly to junior employees in the apprentice shop where many current FIBRO/Läßle staff members began their professional careers. They are working for and managing a company that is rich in tradition, but as young and dynamic as in its earliest days.

FIBRO / LAPPLE





FIBRO INC.

FIBRO OFFERS:

✓ TECHNOLOGY TRANSFER OF 10 YEARS O.H. TRANSFER EXPERIENCE AUTOMATING

MERCEDES BENZ
VOLKSWAGEN
BMW
OPEL
VOLVO
DAF
SAAB
GMC

✓ STOCK MODULES COVER

0 - 2000 LBS. PAYLOAD

0 - 300 FEET TRAVEL DISTANCE

0 - 6 FEET/SECOND SPEED

ELECTRIC OR PNEUMATIC OR HYDRAULIC

✓ CONSULTING ENGINEERING

OPTIMIZE O.H. TRANSFER APPLICATION

SYSTEM RESPONSIBILITY

SERVICE AND STANDARDIZED SPARE PARTS



PREDICTABLE PRICING

ALL O.H. TRANSFERS ARE PRICED AS FOLLOWS:

SYSTEM COST EQUALS:

MODULES AT CATALOG PRICES, PLUS
SYSTEM COST AT A FIXED FEE PER
MODULE WHICH COVERS:

- ✓ **ENGINEERING ANALYSIS**
- ✓ **DESIGN AND DETAIL**
- ✓ **BUILD**
- ✓ **WIRE AND PIPE TO A CENTRAL POINT**
- ✓ **TEST RUN**
- ✓ **CUSTOMER ASSISTANCE**
- ✓ **WARRANTY SERVICE**

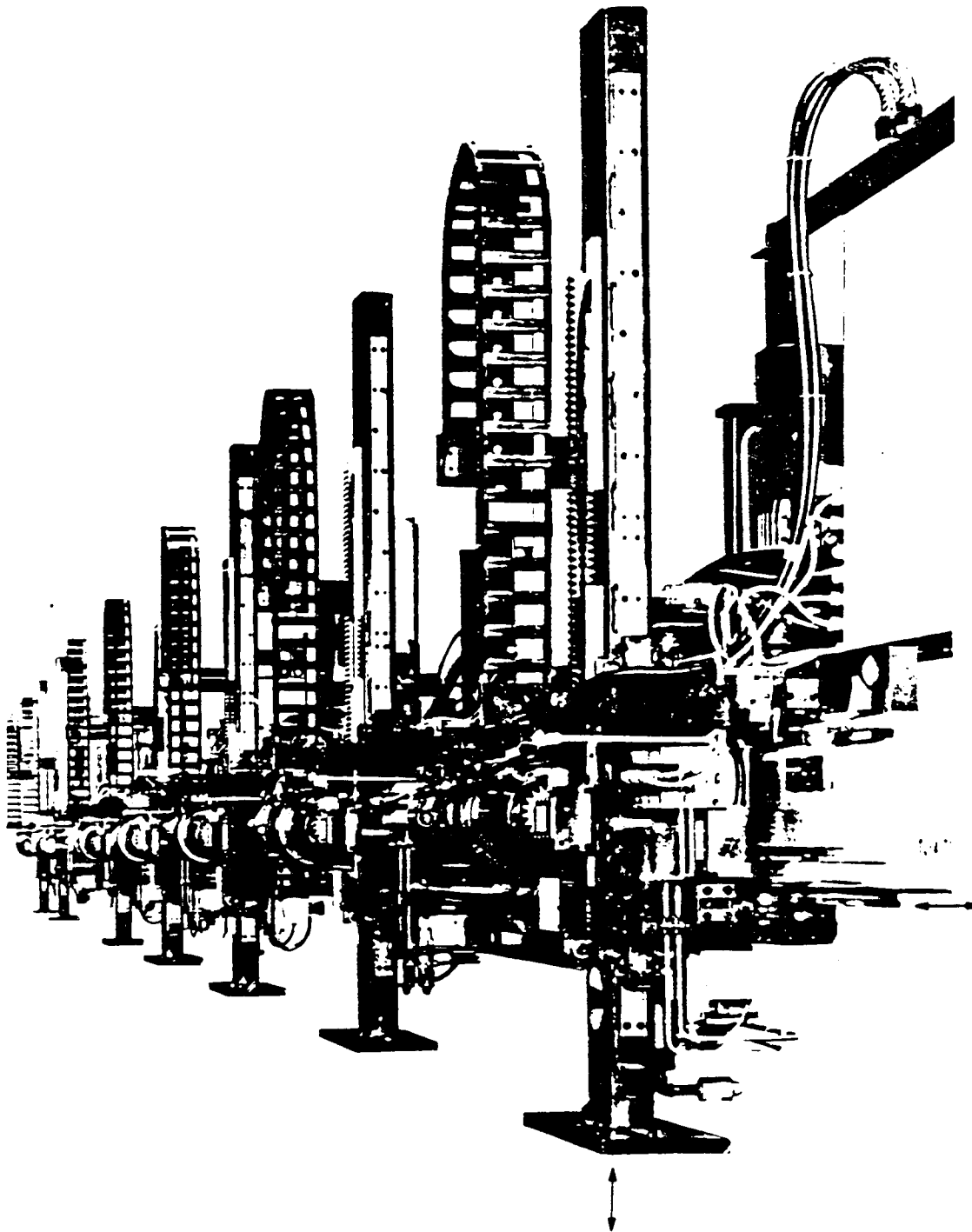
\$3000. — PER MODULE



FIBRO INC.

GANTRY ROBOTS PARTS TRANSFER SYSTEMS

FIBRO INC
SUB OF LAPPLE GROUP
139 HARRISON AVENUE • P.O. BOX 5924 • ROCKFORD, IL 61125
815/229-1300

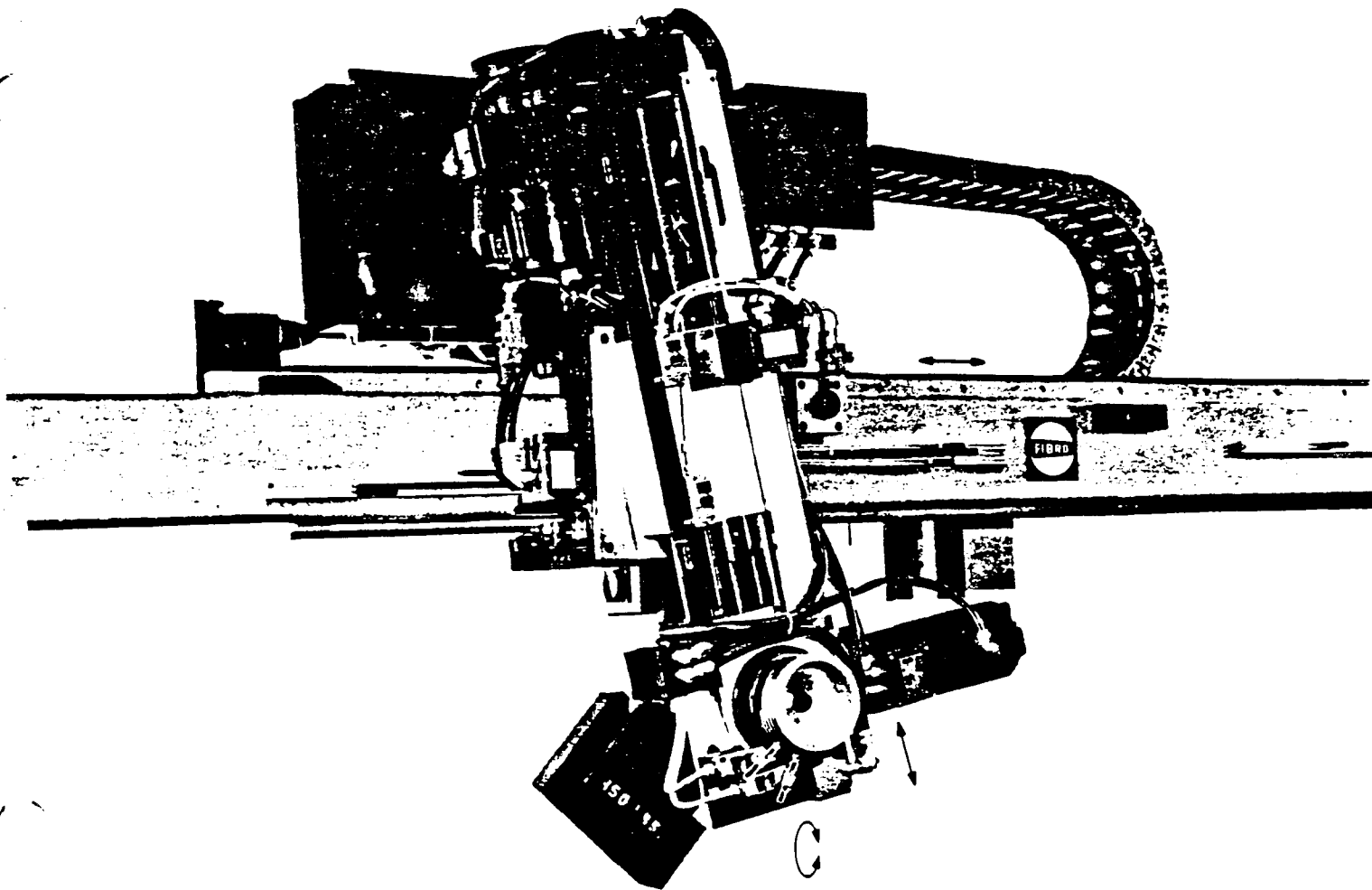


PARTS TRANSFER

7 X 750 LBS. PAYLOAD

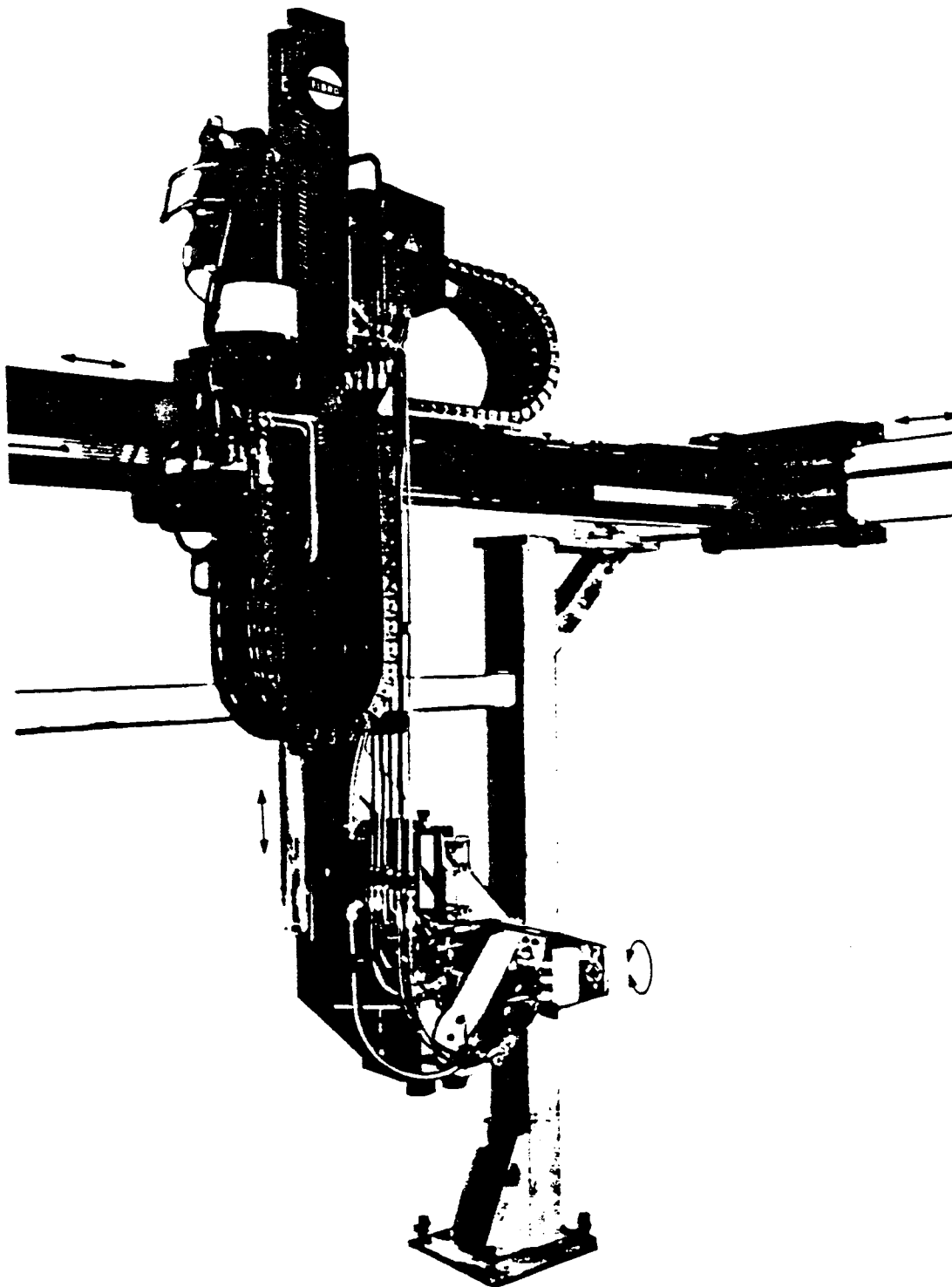
(4) Horizontal Axis: A.C. Drive; 3.3 Ft./Sec

(7) Lifter: A.C. Drive; 1.3 Ft./Sec.



PARTS TRANSFER
150 LBS. PAYLOAD

Horizontal Axis: A.C. Drive; 3.3 Ft./Sec.
Lifter: A.C. Drive; 1.5 Ft./Sec.
Rotary Axis: A.C. Drive; 90° in 2 Seconds

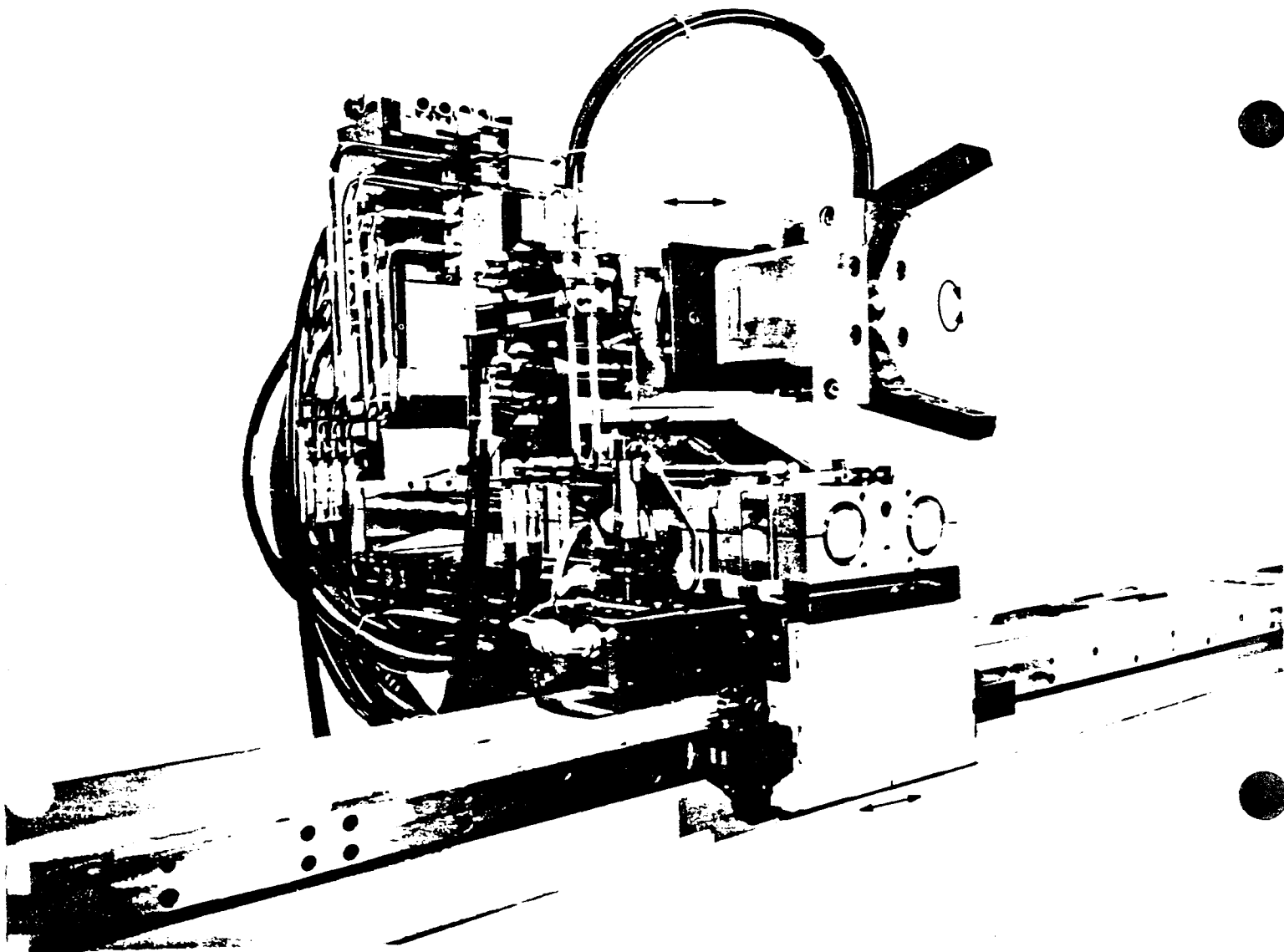


TOOL CHANGER
3 AXIS D.C. SERVO

Horizontal Axis: 4.5 Ft./Sec.

Vertical Axis: 2.5 Ft./Sec.

Rotary Axis: (3) Position; Hydraulic; 90°/Sec.

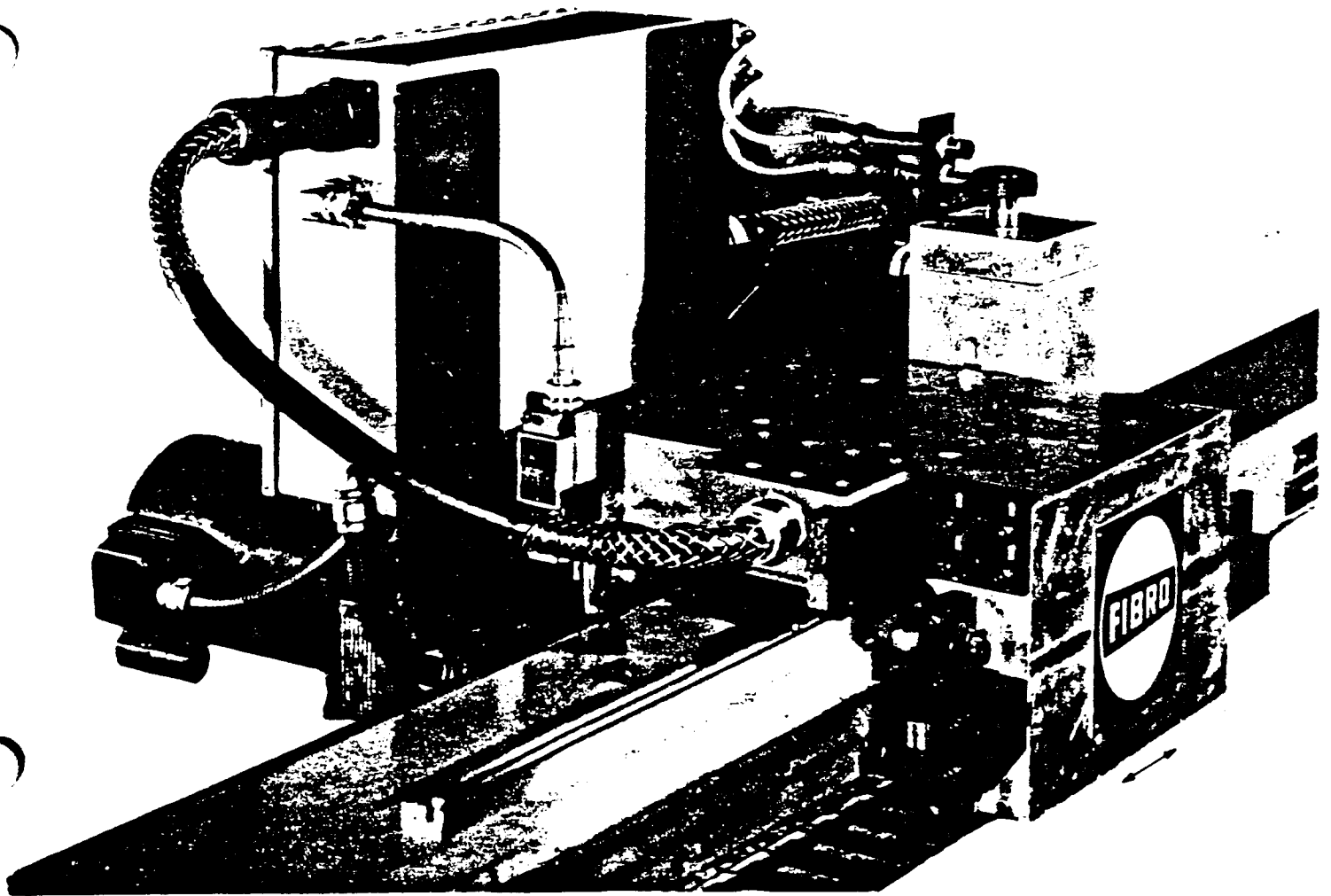


TOOL CHANGER
75 LBS. PAYLOAD

Horizontal Axis: A.C. Drive; 3.3 Ft./Sec.

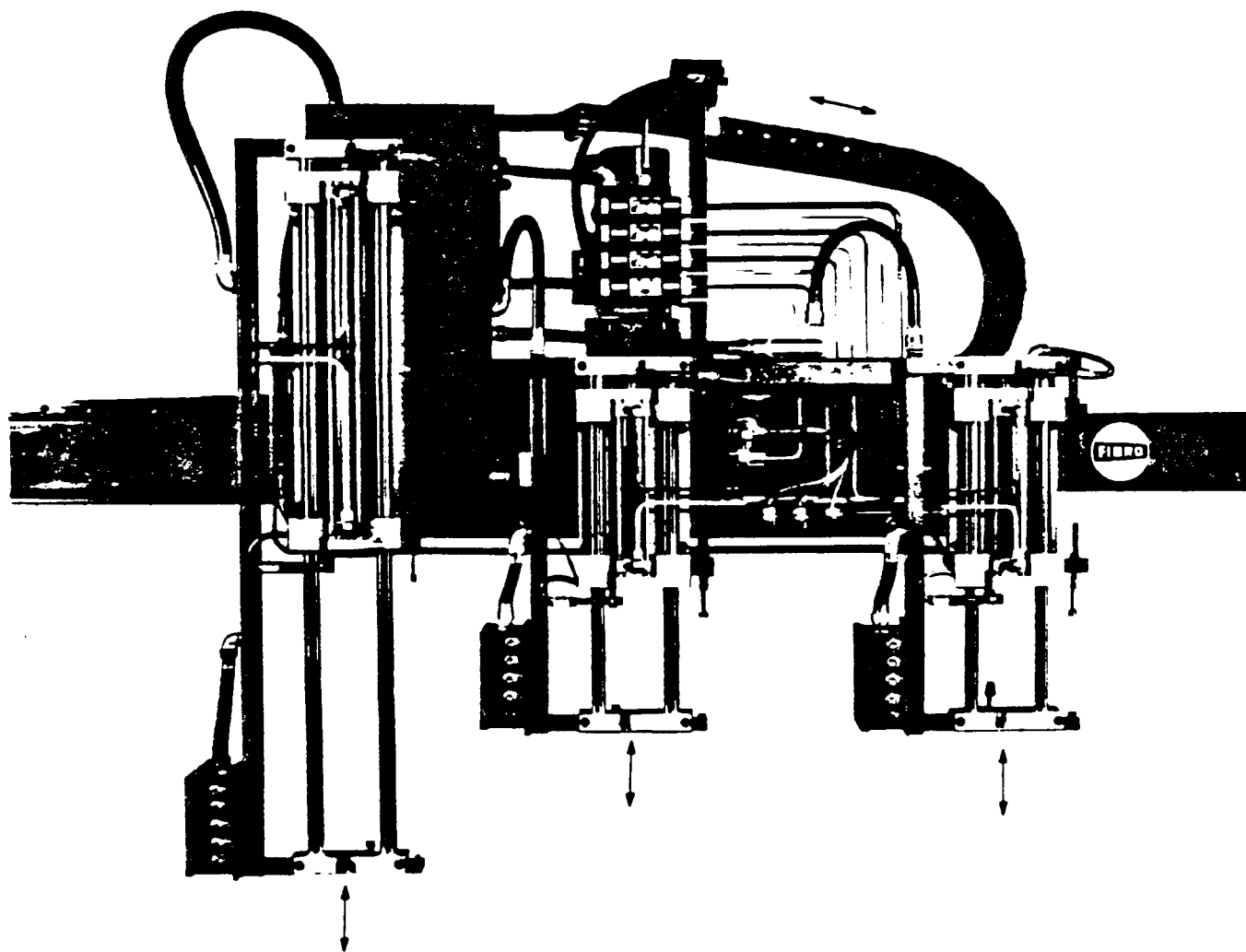
Horizontal Axis: Hydraulic; 15 Inches in .8 Sec.

Rotary Axis: Hydraulic; 90° in 1 Sec.



MONORAIL
700 LBS. PAYLOAD

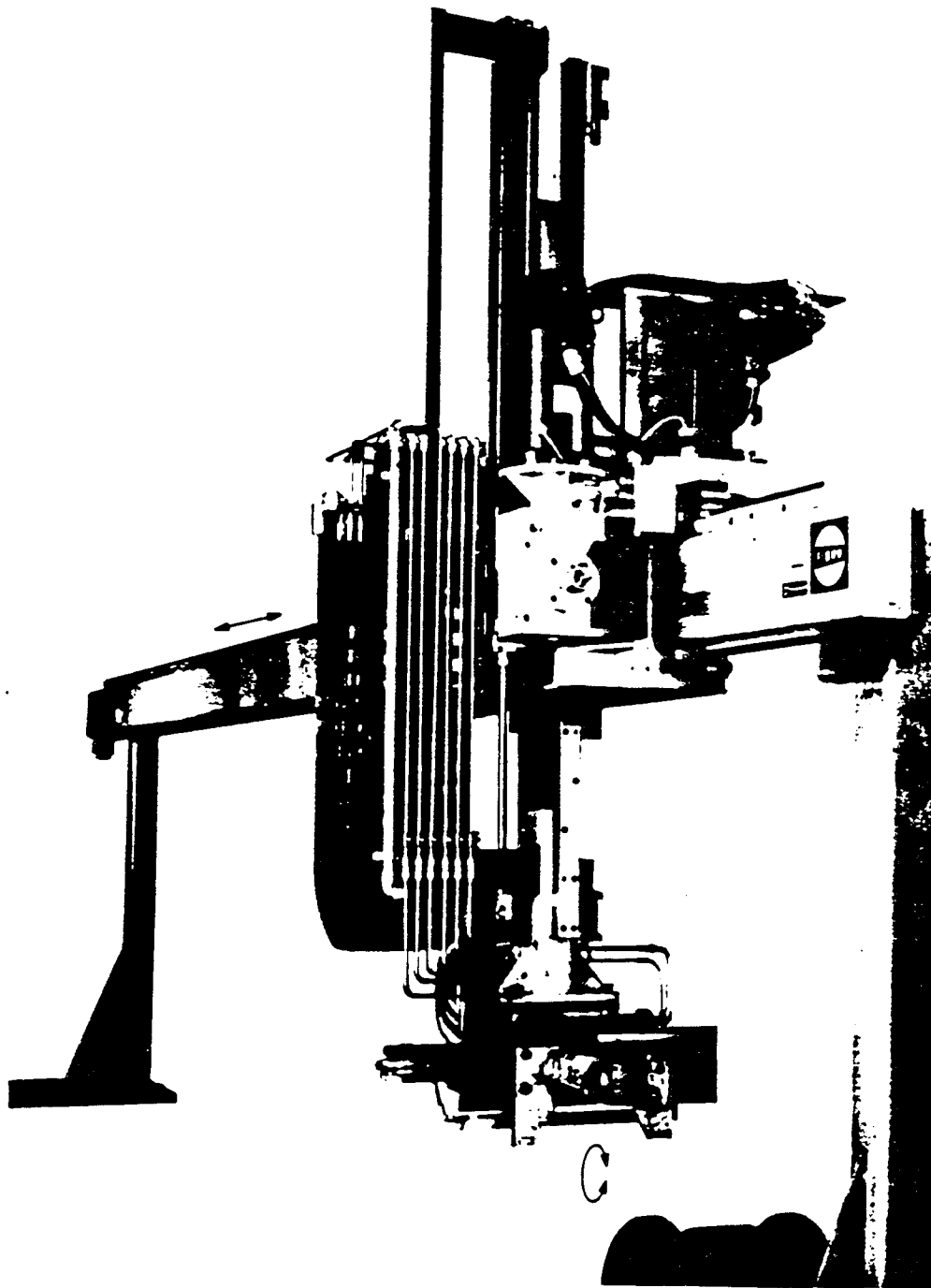
Horizontal Axis Only: A.C. Drive;
3.3 Ft./Sec.; $\pm .005$ Accuracy



PARTS TRANSFER
3 X 150 LBS. PAYLOAD

Horizontal Axis: A.C. Drive; 3.3 Ft./Sec.

(3) Lifter: Pneumatic; 1.0 Ft./Sec.

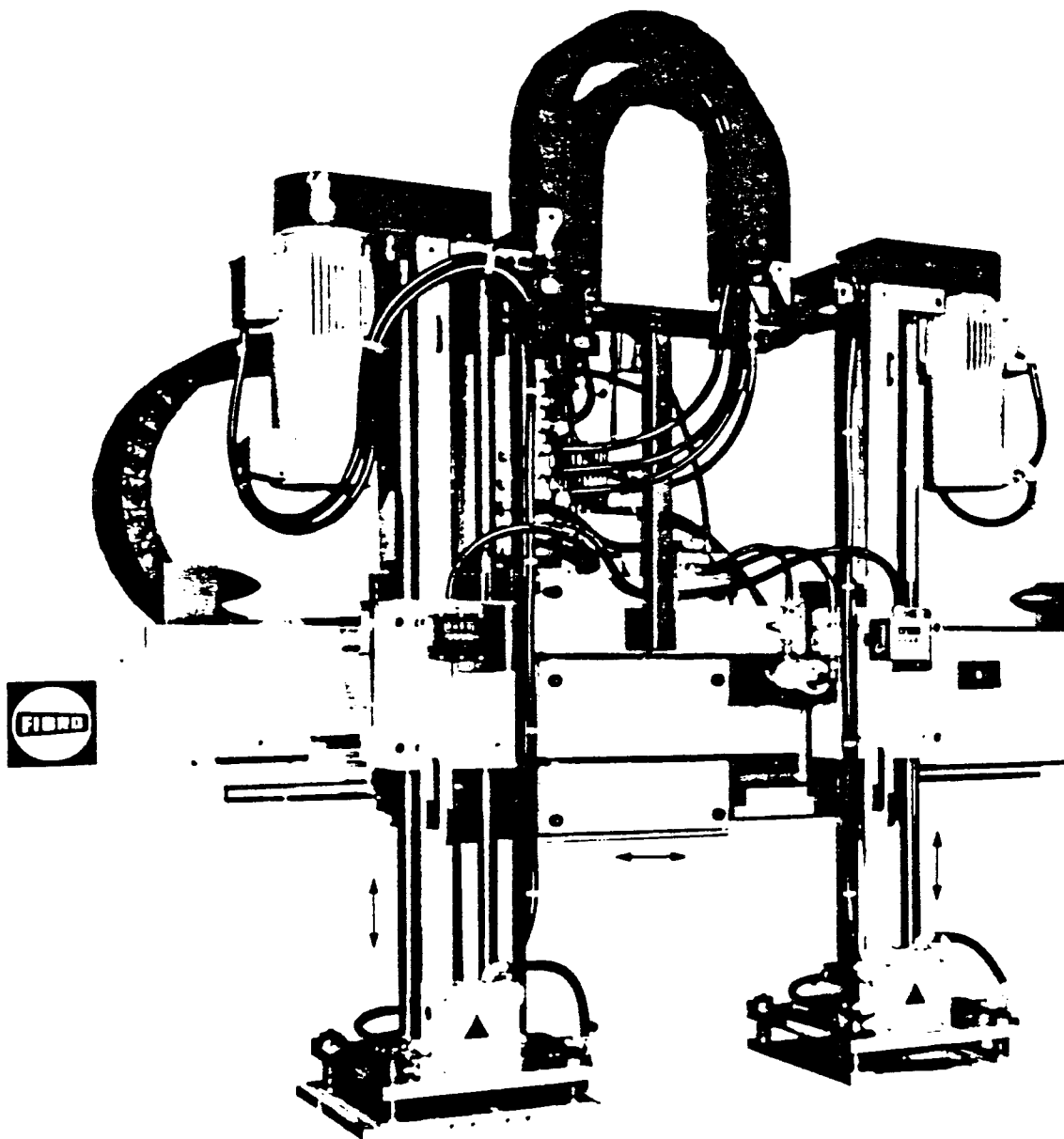


PARTS TRANSFER
300 LBS. PAYLOAD

Horizontal Axis: D.C. Servo; 4.5 Ft./Sec.

Lifter: D.C. Servo; 2.0 Ft./Sec.

Rotary Axis: Hydraulic; 90°/Sec.

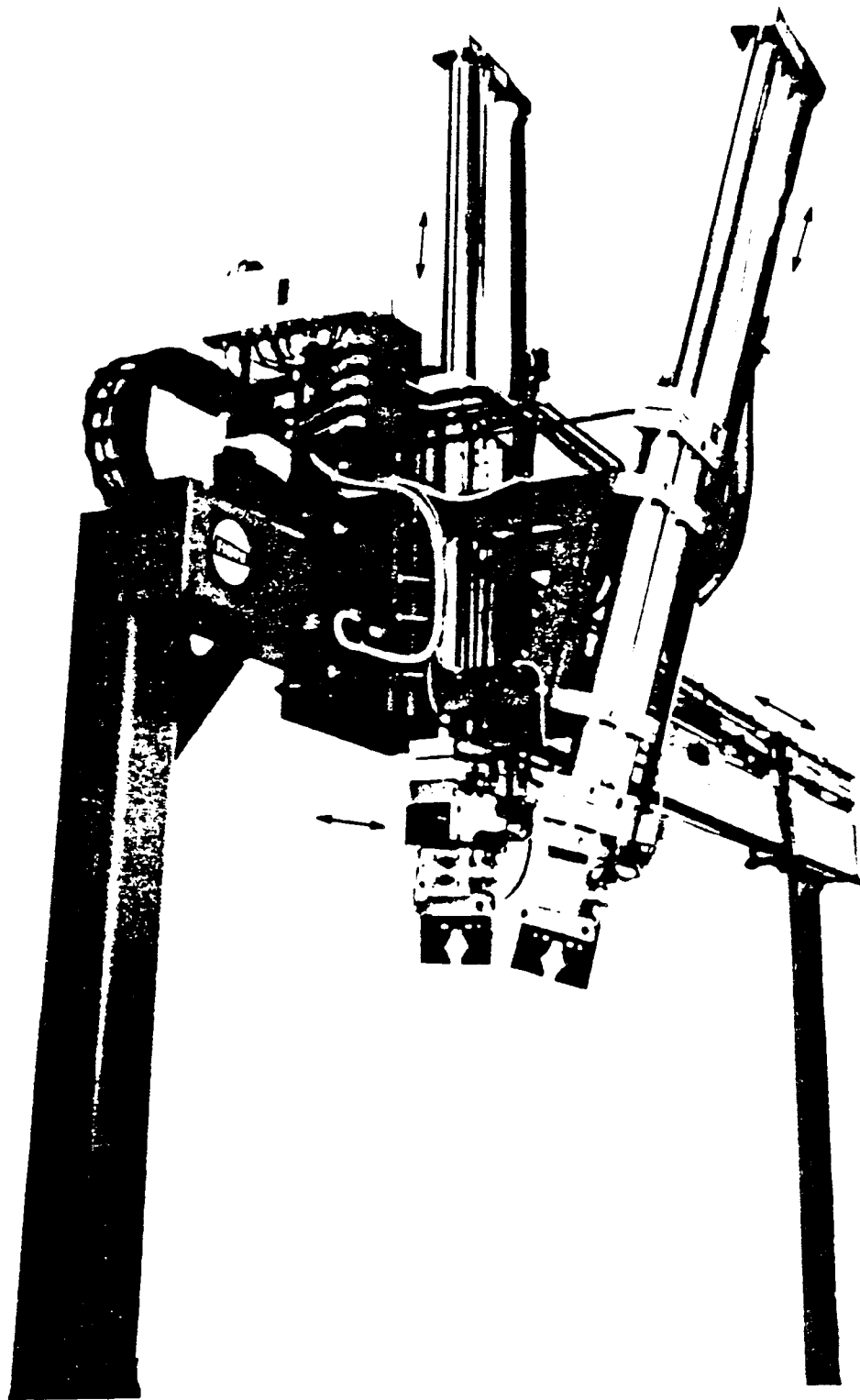


PARTS TRANSFER
2 X 150 LBS. PAYLOAD

Horizontal Axis: A.C. Drive; 3.3 Ft./Sec.

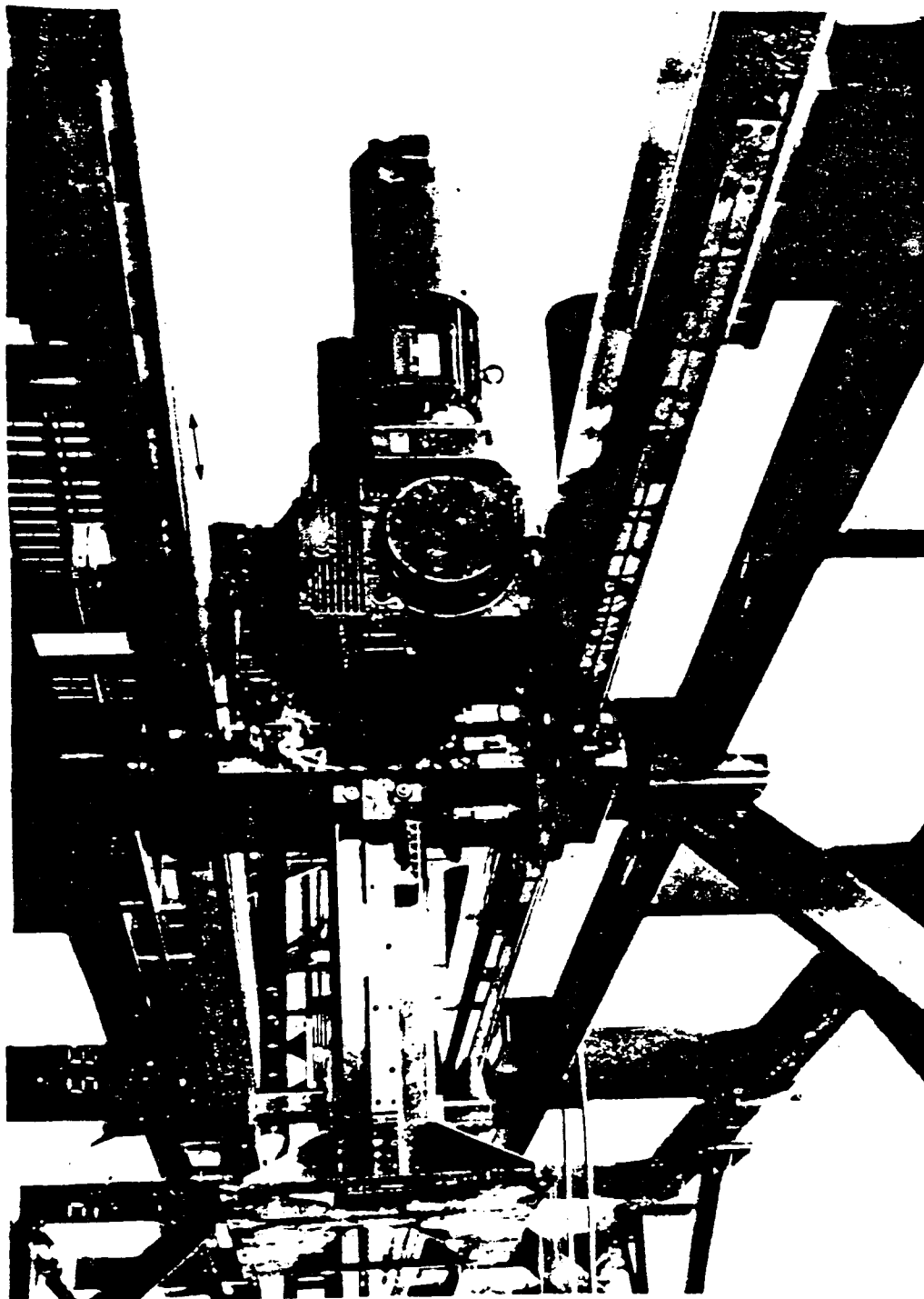
(2) Lifter: A.C. Drive; 1.5 Ft./Sec.

(2) Vertical Compliance Element



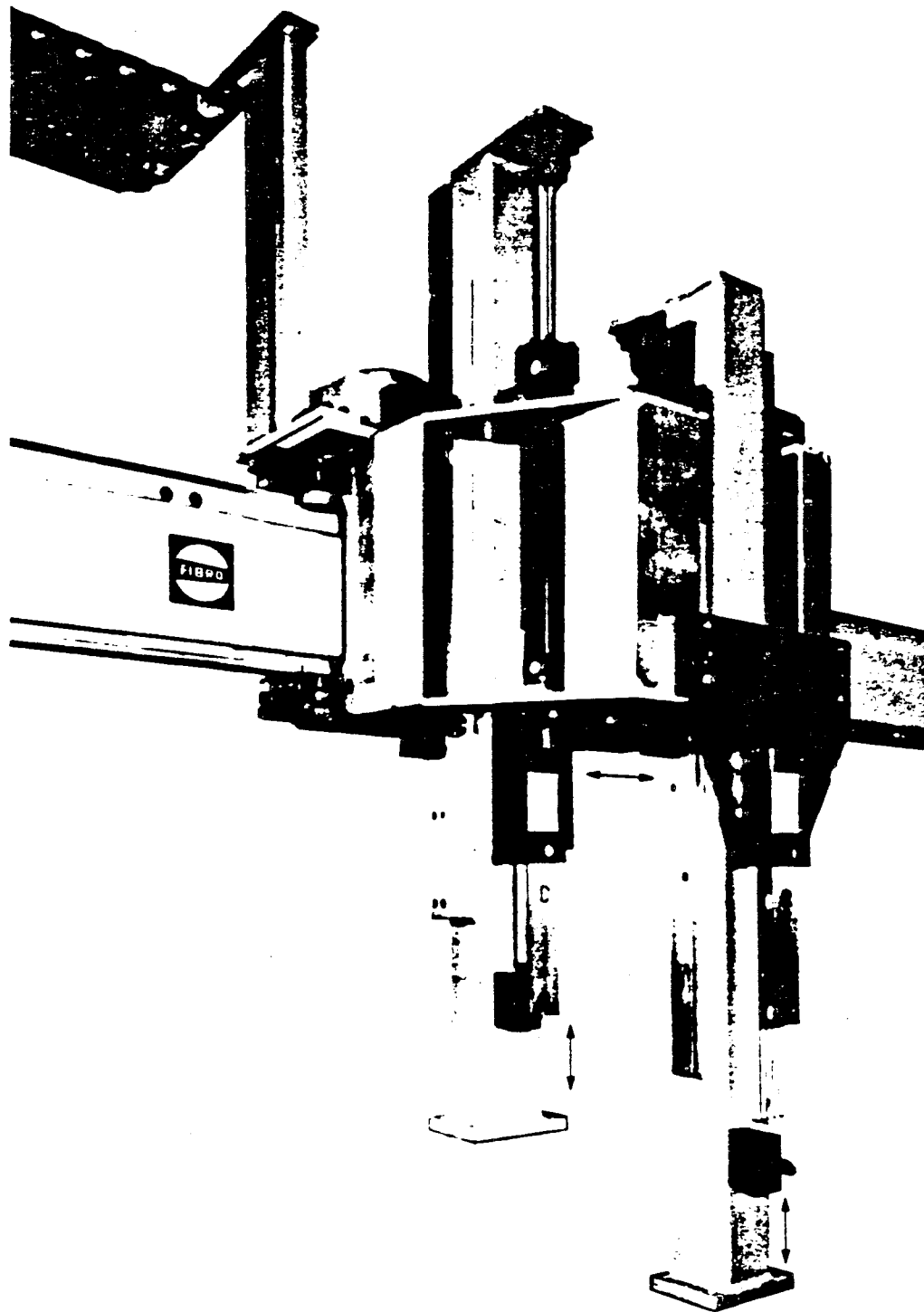
V-LOADER / UNLOADER
2 X 50 LBS. PAYLOAD

Horizontal Axis: A.C. Drive; 3.3 Ft./Sec.
(2) Vertical Axis: Hydraulic; 2 Ft./Sec.
Compliance Element: Horizontal



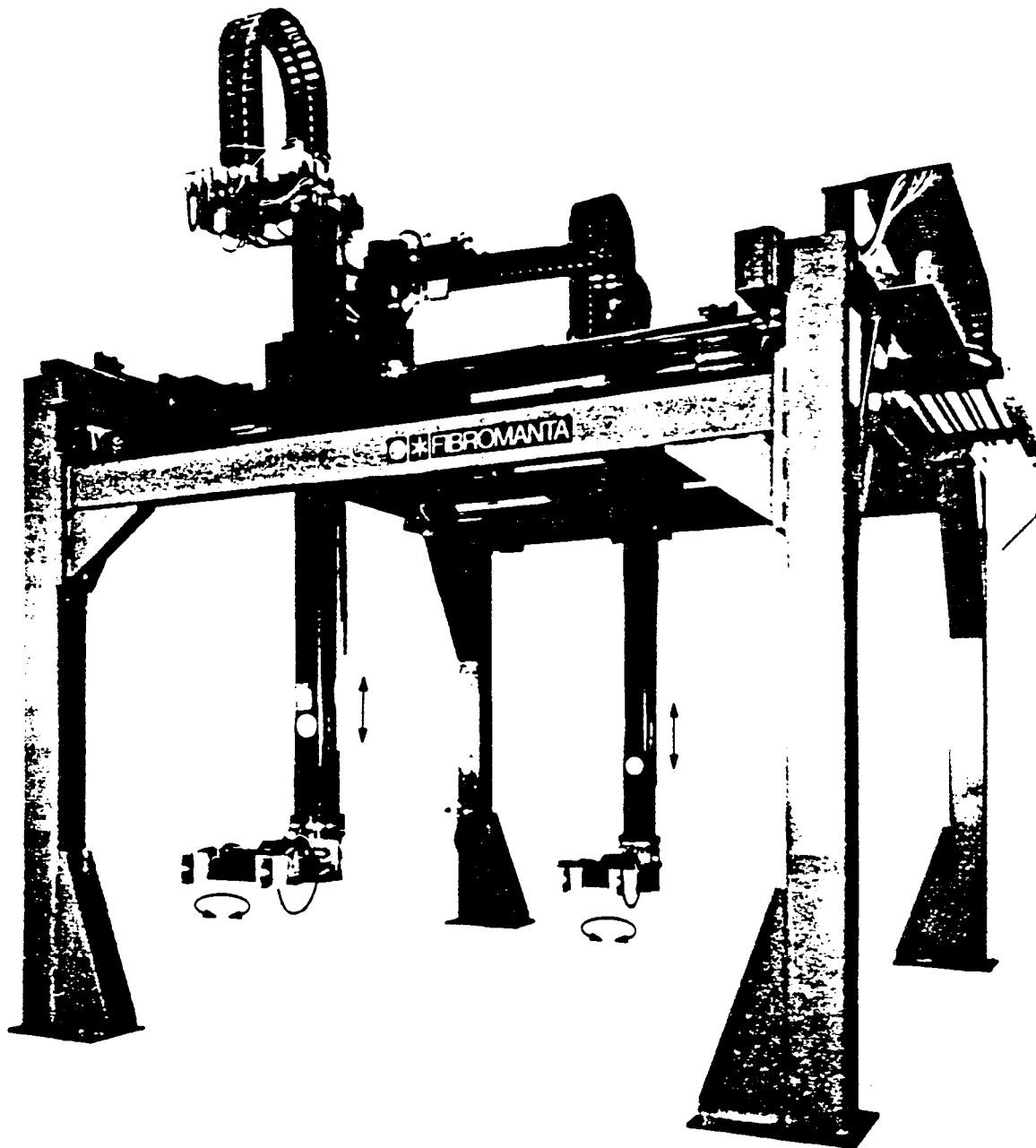
PARTS TRANSFER
9 X 1500 LBS. PAYLOAD

- (9) Horizontal Axis: A.C. Drive; 3.3 Ft./Sec.
- (9) Vertical Axis: A.C. Drive; 1.3 Ft./Sec.



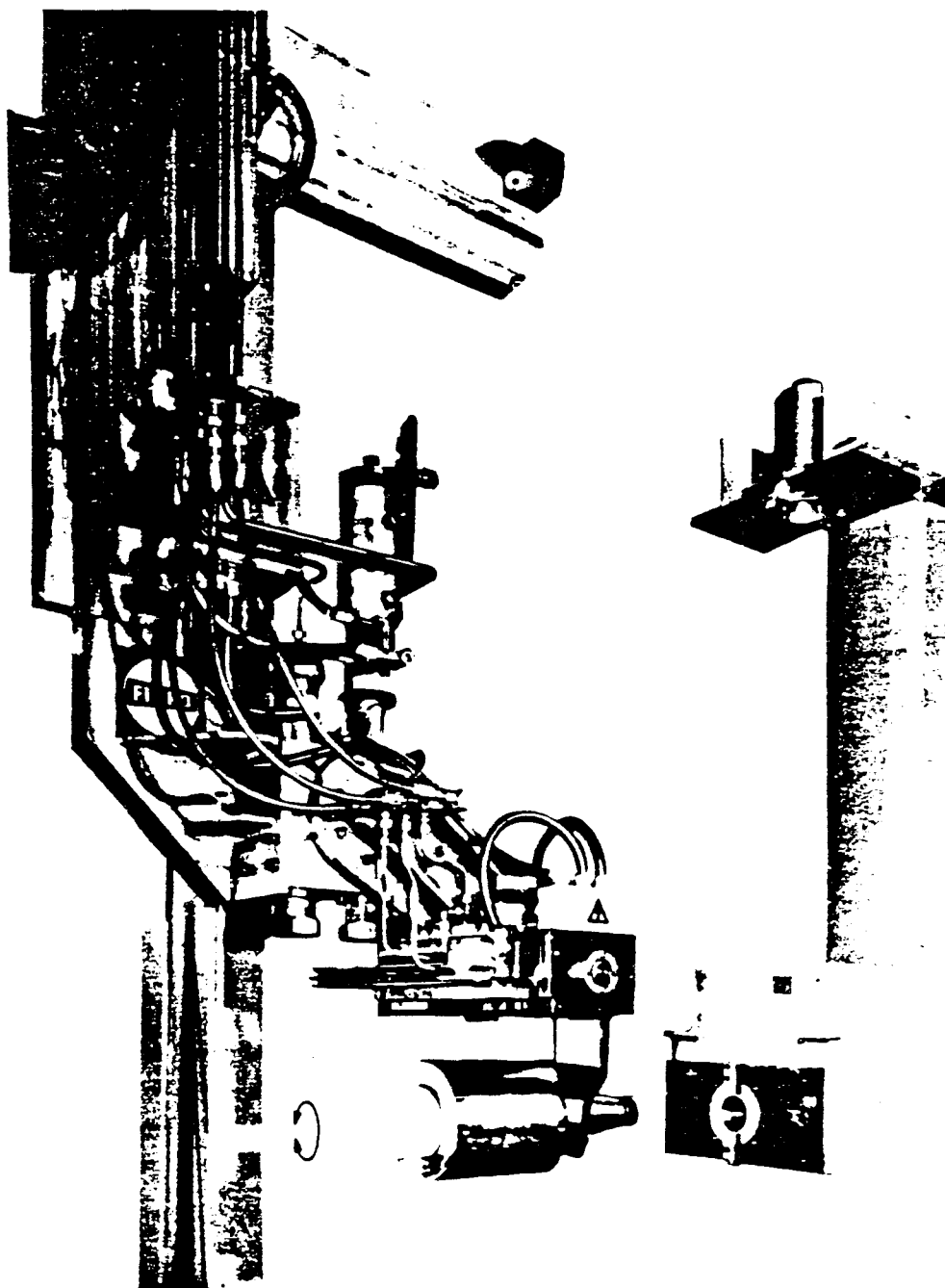
PARTS TRANSFER
2 X 150 LBS. PAYLOAD

Horizontal Axis: A.C. Drive; 3.3 Ft./Sec.
Lifter: Hydraulic; 1 Ft. in .8 Sec.



GANTRY ROBOT
2 X 100 LBS. PAYLOAD

- (10) Axis D.C. Servo
- (4) Horizontal Axis: 5 Ft./Sec.
- (2) Lifter: 2 Ft./Sec.
- (4) Rotary Axis: 90°/Sec.

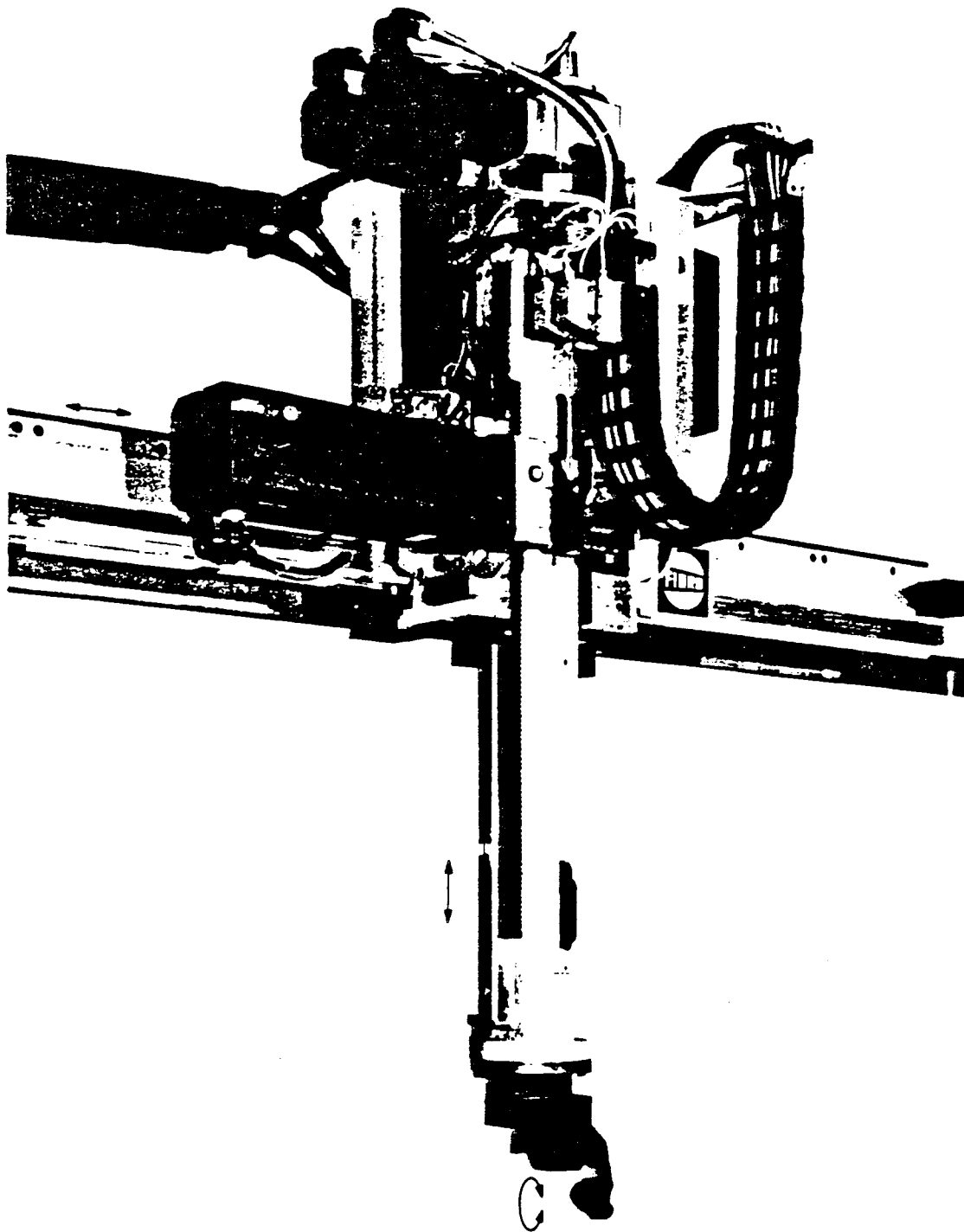


TOOL CHANGER
15 TO 220 LBS. PAYLOAD

Horizontal Axis: D.C. Servo; 4.5 Ft./Sec.

Lifter: D.C. Servo; 2 Ft./Sec.

Rotary Axis: Hydraulic; 90°/Sec.



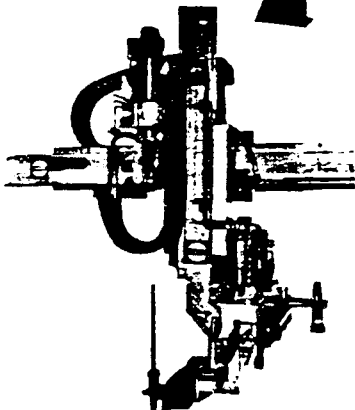
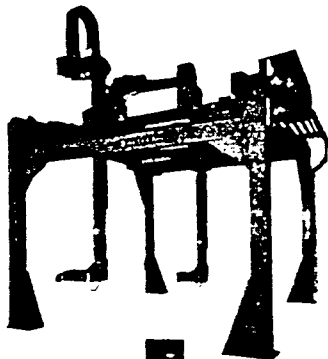
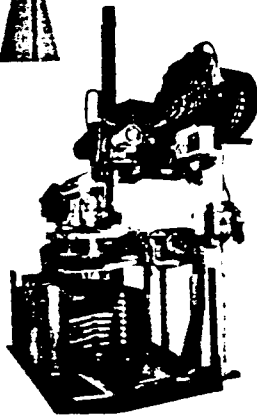
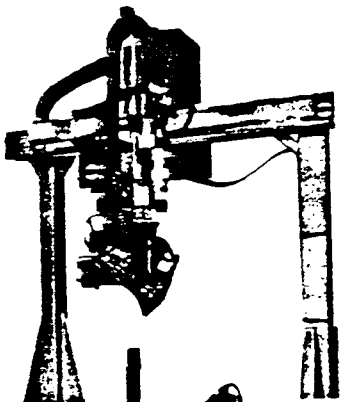
WATER JET CUTTING SYSTEM
5 AXIS A.C. SERVO

Horizontal Speeds to 6 Ft./Sec.

Vertical Speeds to 6 Ft./Sec.

Rotation to 900°/Sec.

(Cuts a 2 Inch Diameter Hole in .7 Seconds)

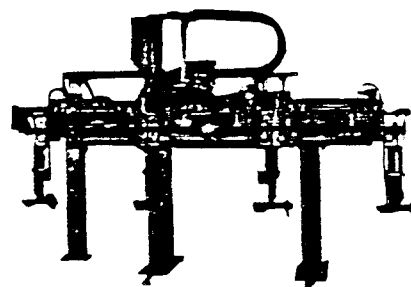
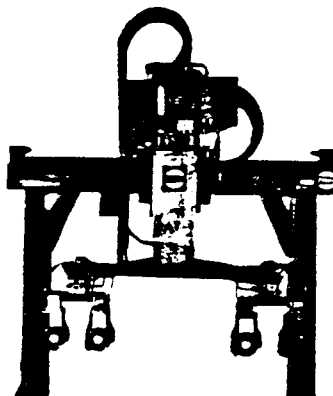


THE FIBRO WORK HANDLING SYSTEM:

A MODULAR APPROACH TO FACTORY AUTOMATION
OFFERING INFINITE OPPORTUNITIES THROUGH CUSTOMIZED DESIGNS. . .

Design and incorporation of automation into the production process presents many challenging questions and decisions. The Fibro modular concept is designed to complement manufacturing objectives by offering customized solutions to material handling applications in such fields as:

- Machine loading/unloading
- Station-to-station transfer
- Toolchanging
- Tool management
- Sheet metal racking
- Palletizing



Fibro Building Block Components are available from stock in over 1000 combinations, offering

- Gripping • Rotary • Linear motions, with actuation by
- Hydraulic • Pneumatic • Electro-Mechanical power in a wide variety of stroke lengths to suit a range of applications.

Minimum data required for quotation purposes is:

- Weight and dimensions of part
- Quantity of parts to be transferred
- Number of pick and place points
- Cycle time requirements
- Drive mode preferred
- Amount of travel in x (horizontal) and z (vertical) planes
- Rotate, tilt, grip and/or y-axis motion requirements

Fibro specializes in building systems from these components for applications which typically meet several of the following qualifications:

<u>Customer Requirement</u>	<u>Fibro Solution</u>
High production rate.....	Velocities to 6 ft./sec.
Heavy part weight.....	Payloads to 2000 lbs.
Long travel length.....	Distances to 300 feet
Precise Part Positioning..	Accuracies to $\pm .004$ inches

Our goal is to provide our customers with solutions for higher productivity by offering a quality product at reasonable cost. Fibro's qualified staff will be pleased to provide assistance in determining your automation needs.

Call 1-800-523-2376 for application analysis.



FIBRO Inc.
P.O. Box 5924 • Rockford, IL 61125

815-229-1300
FAX 815-229-1303 • TELEX 499-2578

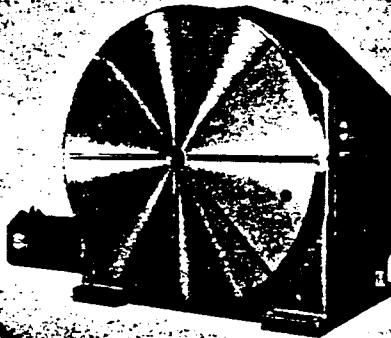
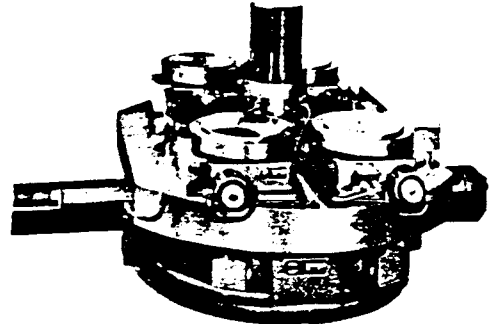
FIBRO ROTARY TABLES

RELIABILITY, PRECISION AND PERFORMANCE FOR THE HEART OF THE MACHINE TOOL CELL



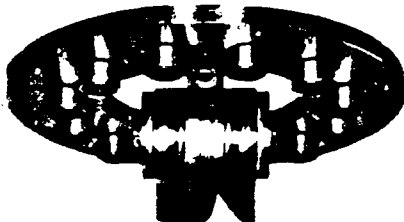
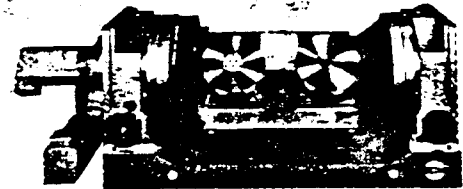
FIBROTAKT®

Face gear tables and table combinations for fixed indexing applications. This model offers high accuracy and rigidity for intense machining forces.



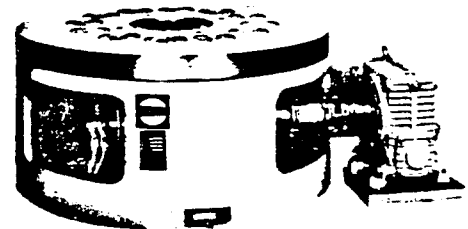
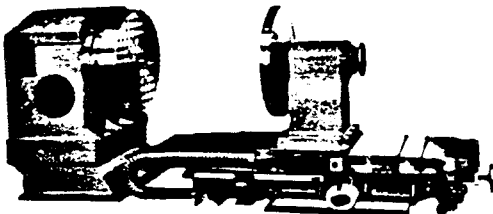
FIBROPLAN®

NC positioning tables and table combinations are ideal for random indexing, contour milling and continuous rotary motion requirements.



FIBROTOR®

This unit uses cam and cam roller operation to provide smooth action for high accuracy, high speed assembly processes.



SPECIAL OFFERINGS

Engineering of table combinations including planetary, pallet designs, slide units and requirements for trunnion and tailstock equipment are part of our advanced product offering...



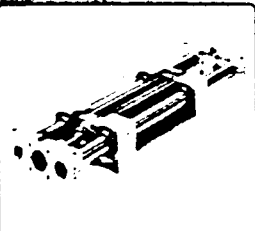

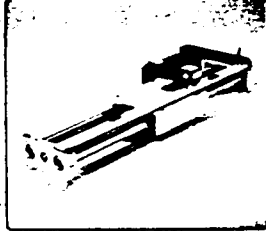
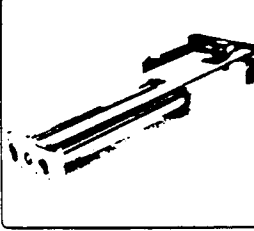
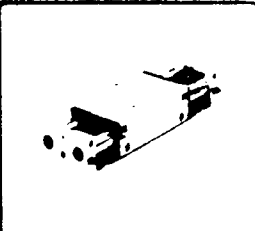
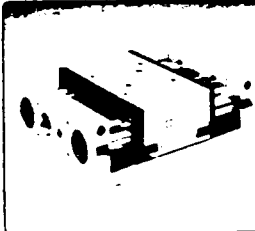
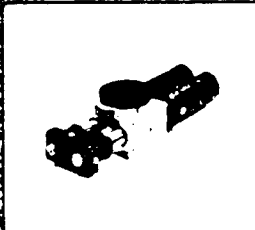



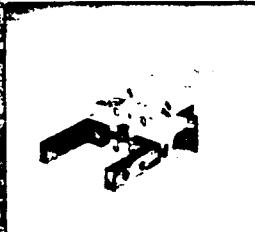
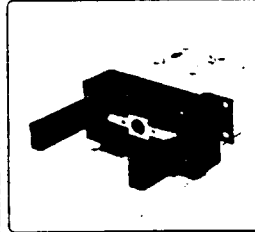
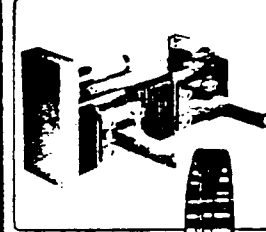
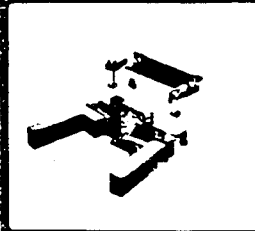
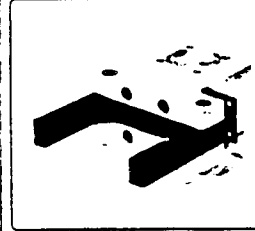
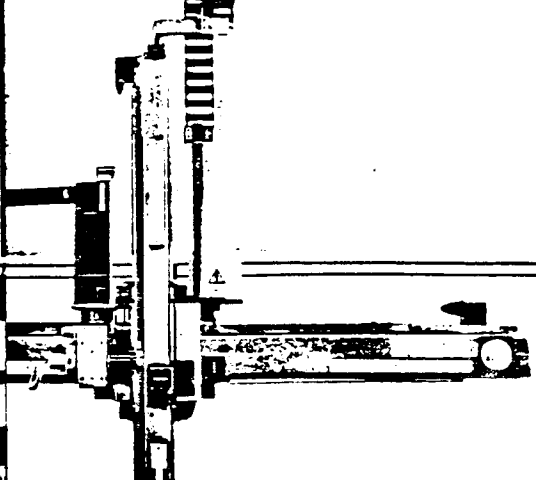

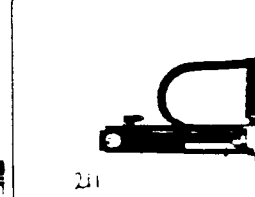
FIBRO Inc.

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Call 1-800-523-2376 for application analysis.



FIBROMANTA® Range of handling modules

	Pneumatic	Hydraulic	Motorised	
Translation	 52.11.4	 On request 52.15.5	 52.17.4	 52.17.5
Short stroke	 52.25.4	 52.21.5		
Rotation	 52.51.4	 51.55.5	 51.57.4	 51.57.5
Gripping parallel movement	 52.81.4	 51.85.5	 51.87.4	
Gripping angular movement	 51.71.4	 51.75.5		
Beam carriage cross beam carriage (Gantry-Type)				

Corporate Report

FLOW is the world's leader
in ultrahigh-pressure
waterjets and abrasivejets for
industrial cutting and milling.

FLOW

FLOW
SYSTEMS, INC.

THE COMPANY

FLOW is the world's leader in ultrahigh-pressure waterjets and abrasivejets for industrial cutting and milling.

Since 1974, *FLOW* has delivered more than 1,000 waterjet and abrasivejet systems to a variety of industries in 43 countries. *FLOW* accounts for more than 70 percent of worldwide sales of such systems.

FLOW has two divisions:

- Flow Systems Division sells waterjet and abrasivejet systems worldwide to end-users and original equipment manufacturers ("OEMs").
- Flow Services Division offers ultrahigh-pressure jetting services in the United States and Canada for:
 - Hydromilling of deteriorated concrete from highway bridges, parking garages, and concrete structures;
 - Jetting services for industrial surface preparation, cutting, and cleaning.

The use of waterjet as an industrial cutting and milling tool is an emerging technology. *FLOW* is at the forefront in developing new applications and enhancing existing ones. In addition, *FLOW* actively seeks the cooperation of its customers, OEMs, distributors, sales agents, and joint-venture partners to develop new applications worldwide.

THE TECHNOLOGY

FLOW's ultrahigh-pressure intensifier pump pressurizes water up to 55,000 psi and forces it through a nozzle, as small as 0.004 inches in diameter, generating a high-velocity waterjet at speeds up to 3,000 feet per second. This waterjet can cut a variety of non-metallic materials.

To cut metallic or hard materials, *FLOW* has developed a device that entrains abrasives into the waterjet to enhance the cutting capability. This high-velocity abrasivejet ("*PASER*"*) can cut virtually any material.

THE CAPABILITY

- *FLOW* provides the most advanced:
 - Ultrahigh-pressure *Intensifier Pumps* that can pressurize water up to 55,000 psi.
 - Ultrahigh-pressure *Accessories* such as tubing, hoses, waterjet nozzles, instant on/off valves, swivels, abrasivejet devices, and others.
- *FLOW* provides solutions to a variety of industrial cutting and cleaning problems with reliable, user-friendly waterjet and abrasive tools and systems, such as:
 - *Hand-held Waterrouter, Jet Wand, and Jetlance*
 - *Slitting and Cross Cutting Systems*
 - *ShapeCutting Systems*
 - *Robotic Cutting/Cleaning Systems*
- *FLOW* strives to provide high-quality products and services to our customers. If our standard tools and systems cannot solve customers' cutting and cleaning problems, *FLOW* will develop *Custom-Designed Systems*.
- *FLOW* offers jetting services in the United States and Canada using ultrahigh-pressure waterjet and abrasivejet systems.

THE OPERATIONS

FLOW has operations centers in North America, Europe, and Asia, each with marketing, sales, service, application engineering, and systems integration capabilities.

ON THE COVER

FLOW cutting systems are used worldwide to cut a myriad of metallic and non-metallic materials. The *FLOW* block letters on the cover were cut by *FLOW* waterjet/abrasivejet from (left to right) granite, concrete, glass and corrugated board.

FLOW
SYSTEMS
DIVISION

FLOW SYSTEMS^{INC.}

THE BUSINESS

To develop, design, manufacture, sell and service waterjet and abrasivejet systems worldwide to end-users and original equipment manufacturers for automated industrial cutting, drilling, milling, and cleaning applications.

THE ADVANTAGES

The advantages of ultrahigh-pressure waterjet and abrasivejet cutting over conventional cutting methods are the following:

- Waterjet cutting is omni-directional. It is easily adaptable to a variety of computer-controlled motion systems to cut complex shapes.
- Waterjet is "non-contact" cutting; it avoids the need for frequent cleaning and/or sharpening of mechanical knives or saws.
- Waterjet cutting exerts minimal lateral force, greatly simplifying material handling. This feature also enables waterjets to cut very close to the material edge, thereby reducing waste.
- Waterjet cutting generates no airborne dust.
- Waterjet slitting of continuous web products increases productivity over traditional methods because of its higher cutting speed.
- Waterjet cutting does not crush the edges of materials.
- Abrasivejet cutting generates little heat, making it ideal for cutting heat-sensitive materials.
- Abrasivejets cut hard-to-cut materials, leaving a quality edge.

PRECEDING PAGE

Light-weight, open-cell foam is being slit by FLOW's waterjet. The waterjet has the unique ability to slit very light materials, like foam, with no distortion. It can slit thin strips easily and quickly.

PHOTO AT RIGHT

Fifty-pound basis weight kraft liner-board is slit at 2,000 feet-per-minute at FLOW's lab. This same material is being slit at 6,000 feet-per-minute on a customer's rewinder.



FLOW'S PRODUCTS

During the past 14 years, *FLOW* has developed ultrahigh-pressure intensifier pumps and accessories, hand-tools, and computer controlled motion systems to make the waterjet and abrasivejet useful tools for industrial cutting and milling applications.

• Pumps and Accessories.

- *Intensifier Pumps.* *FLOW* offers a line of the most advanced and reliable ultrahigh-pressure intensifier pumps that can pressurize water up to 55,000 psi.
- *Accessories.* *FLOW* offers an array of ultrahigh-pressure accessories that transport the pressurized water to cutting or cleaning stations, and convert it into a high-velocity waterjet with or without abrasives. Such accessories include ultrahigh-pressure tubing, hoses, swivels, on/off valves, and waterjet nozzles.

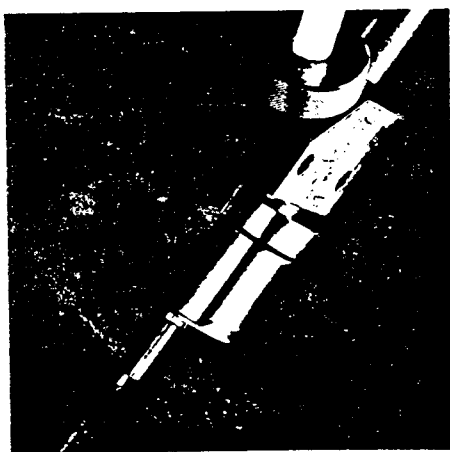
• Abrasivejet Device.

FLOW's abrasivejet ("*PASER*"), introduced in 1984, was a major advance in jet cutting technology. While the waterjet cuts non-metallic materials, *PASER* cuts virtually any material. Abrasives, such as garnet or aluminum oxide, are entrained in the high-velocity waterjet, and the resulting abrasivejet cuts thick metal plates, composite materials, ceramics and glass. *PASER* cuts with little heat, causes no metallurgical changes, and leaves a quality edge that usually requires no additional finishing. *PASER* is easily integrated with computer controlled motion systems. *FLOW*, together with its OEMs, distributors, and affiliated systems houses, has integrated *PASER* devices with computer controlled motion systems from major manufacturers around the world.

• Hand-held Tools.

These tools cut and clean efficiently:

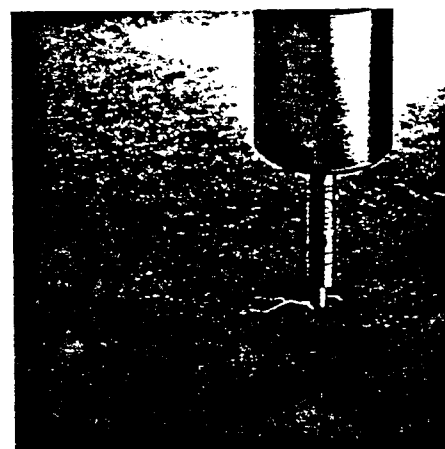
- *Waterrouter®* is a hand-held shape cutting device for cutting and trimming



Aerospace Applications. Abrasivejet Cutting of Advanced Composites and Heat-Sensitive Materials. *FLOW*'s abrasivejet can cut virtually any material without significant heat buildup or metallurgical change. The aerospace industry uses both abrasivejets and waterjets to cut Kevlar® graphite or boron composites, and to cut heat-sensitive materials such as aluminum alloys, stainless steel, Inconel® and titanium. Integrated with robotic systems, *PASER* can perform complex contour cutting and drilling tasks in a single pass.



Aerospace Applications. Abrasivejet cutting of Stainless Steel. *PASER* cuts complex stainless steel aircraft parts quickly and precisely without generating excessive heat.



Aerospace Applications. Abrasivejet Cutting of Thick Composites. Thick composite materials are cut with *PASER*. Conventional cutting tools tend to delaminate bonded surfaces and cause heat buildup that ruins the edge quality. *FLOW*'s *PASER* cuts much faster, produces a quality edge that is smooth and not affected by heat.

fiberglass, Kevlar, and graphite materials. Its articulated boom allows the cutting of large and complex shapes.

- *JetWand™* is a non-rotating ultrahigh-pressure jetting tool for removing tough and thick deposits from a variety of surfaces; for example, mill scale, bonded rubber, paint, polymers and biogrowth.
- *JetLance™* is a rotating ultrahigh-pressure jetting tool. Rapidly spinning waterjets clean coatings or deposits (such as paints, epoxies, sealants, polymers, rust, scale, biogrowths, and laitance) from all types of surfaces. In addition, this tool will effectively scarify concrete surfaces.

The combination of ultrahigh-pressure and low flow rate produces low reaction force, making these tools much easier to handle than conventional waterblasters. In addition, the tool produces a very small amount of wastewater, which greatly reduces the cost of waste disposal. The flexibility and portability of these tools, along with their speed, productivity,

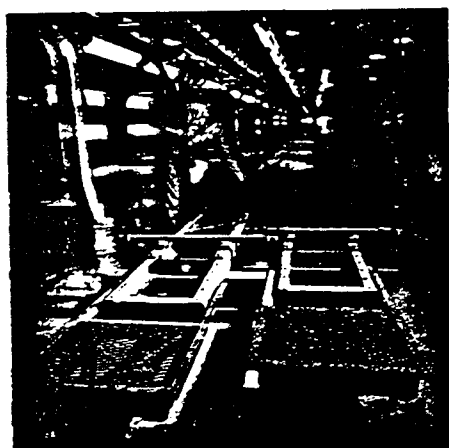
and quality make them logical choices to replace chemical cleaning or low-pressure, high volume waterblasting.

• Slitting Systems.

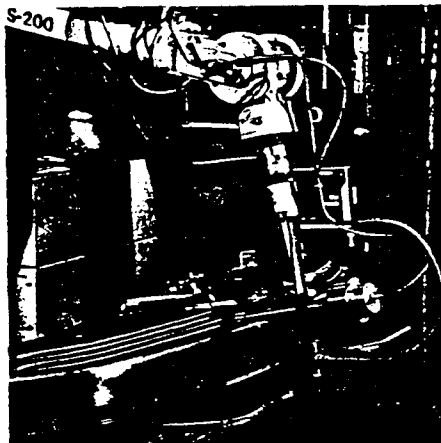
FLOW offers a computer-controlled slitting system with multiple waterjets for continuous web product lines. It provides manufacturers with a solution to many of the problems associated with conventional knife slitting. The waterjet slitter produces a high-quality product, cleaner, faster, and at lower cost. *FLOW* also provides manually positioned slitting systems for customers who do not require frequent re-positioning.

• Edge Trimming Systems.

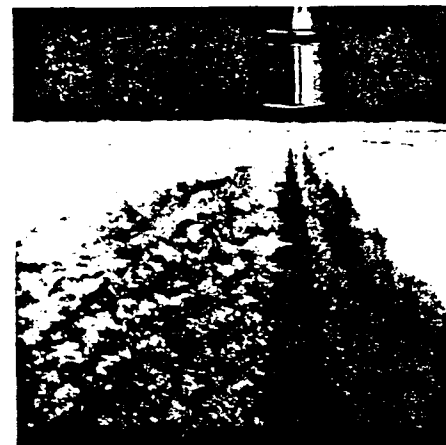
FLOW offers an edge trimming system for continuous web product line. Waterjet cutting produces a quality edge, it does not generate airborne dust, and it can enter and exit a moving web while cutting. Because waterjet cutting exerts minimal force on the material many users are able to increase line speeds.



Automotive Applications. Waterjet Cleaning of Car-body Carriers, Paint Booths and Racks in Auto Assembly Plants. Paint-clogged surfaces are cleaned in seconds with ultrahigh-pressure waterjets. This auto assembly plant uses *FLOW*'s waterjets to clean car-body carriers, paint booths, and racks, replacing the lower-pressure water-blasting that uses much more water and generates high volumes of waste. *FLOW*'s high-velocity, low-volume waterjets at 35,000 psi cut through thick deposits cleanly, reducing waste-disposal costs by as much as 80 percent.



Automotive Applications. Waterjet Cutting of Bumpers in Auto Assembly Plants. *FLOW*'s ultrahigh-pressure waterjet helped one of Detroit's Big Three create a limited edition automobile bumper by modifying a standard design. *FLOW*'s engineers installed the waterjet on a robot that cuts the required contours, up to three inches away from the nozzle, producing consistently high-quality parts that require no hand finishing.



Building Products Applications. Waterjet Slitting and Cross-cutting of Fiberglass Insulation. A large amount of the fiberglass insulation produced in the world is slit by *FLOW*'s waterjets. These slitters do not generate airborne dust and cost less to maintain than mechanical saws. With waterjet slitting systems, fiberglass insulation manufacturers produce accurately cut, higher quality products at a lower cost. In addition, waterjet slitting does not generate airborne fiberglass dust and thus provides a much better and healthier plant working environment.

- **CrossCutting System.**

FLOW offers a crosscutting system to manufacturers of difficult-to-cut web products, such as fiberglass insulation. This reliable, accurate, and dust-free system replaces conventional guillotine cutters and saws. *FLOW*'s unique design produces precision crosscuts on continuous webs even at variable line speeds.

- **ShapeCutting Systems.**

FLOW offers three types of computer-controlled waterjet and abrasivejet shape cutting systems:

- Systems in which the material is stationary and the waterjet or abrasivejet moves in the X-Y plane, for cutting large and heavy plates up to 6 ft. x 10 ft.
- Systems in which the waterjet or abrasivejet is stationary and the material moves in the X-Y plane, for cutting small and lightweight plates smaller than 3 ft. x 3 ft.
- Systems in which the material moves along the X-axis and the waterjet or

abrasivejet moves along the Y-axis, for simplifying material handling and giving improved access to the work area for cutting material such as auto window glass.

- **Custom-Designed Systems.**

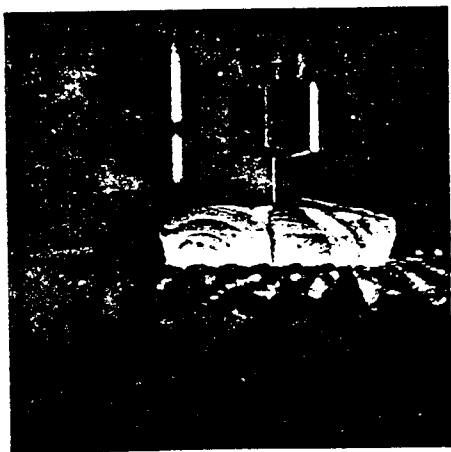
Many of *FLOW*'s customers require specially designed waterjet or abrasivejet cutting systems to solve their cutting problems. *FLOW*, together with its OEMs, distributors, and affiliated systems houses, has a broad range of systems design and manufacturing capabilities to deliver total turn-key systems.

THE APPLICATIONS

FLOW's waterjet and abrasivejet systems are being used in a broad spectrum of industrial cutting and cleaning applications:

- **Aerospace and Defense Industries:**

- Waterjet cutting of uncured, pre-impregnated as well as cured composites.
- Abrasivejet cutting of thick composite materials.



Food Processing Applications. The food processing industry increasingly turns to waterjets for better productivity, less waste, improved sanitation and more precise portioning. Waterjet cutting systems are USDA-approved for cutting food products. Waterjets slit and crosscut candies, bread dough and bakery goods. Coupled with a vision system, waterjets can portion precise weights and sizes of fish, poultry, and processed meats. Fresh or frozen vegetables are quickly sliced or diced for packaging. Waterjet cutting eliminates top edge rollover and crushed edges, and it easily cuts straight lines as well as complex shapes. Waterjets cut without heat build-up, reducing cell damage and increasing shelf life.

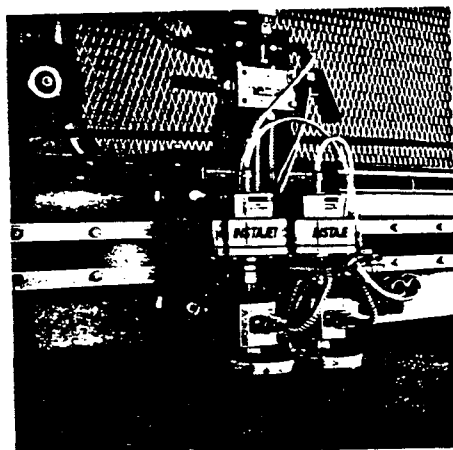


Fiberglass Applications. Waterjet Cutting of Molded Fiberglass Helmets. *FLOW*'s waterjets adapt easily to automated multi-axis cutting systems. Illustrated here is the visor cut in a molded fiberglass helmet. It only requires simple command changes to *FLOW*'s computer-controlled waterjet system to cut a variety of styles at the same workstation.

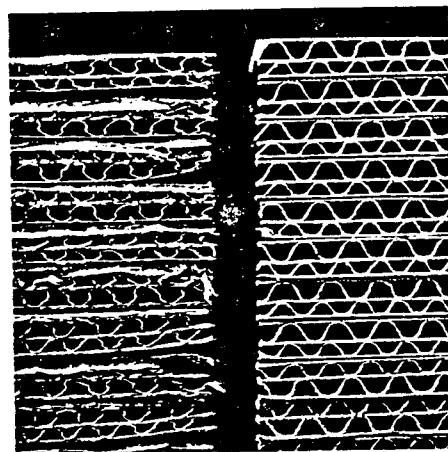


Paper, Tissue, and Packaging Materials Applications. Waterjet Slitting of Web Products. Paper and tissue mills are major users of *FLOW*'s Slitting Systems. Waterjet slitters can be positioned precisely and automatically, right on the paper or tissue machine, thus eliminating costly secondary rewinding. Waterjets cut much faster, allowing faster line speeds with fewer web breaks. Moreover, they create no airborne dust, which enhances printing quality and reduces cleanup and downtime.

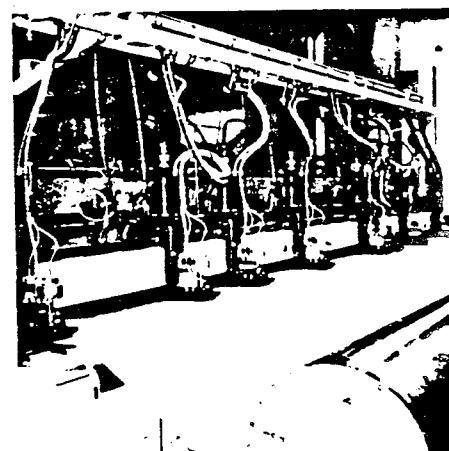
- Abrasivejet cutting of high value heat-sensitive metals, such as aluminum alloys, stainless steel, titanium, and Inconel®.
- **Automotive Industry:**
 - Shape cutting of instrument panels, carpets, door panels, headliners, bumpers, fascia panels, window glass, mirrors, and other interior and exterior components.
 - Cleaning of car body carriers, paint booths, and racks.
- **Building Products Industry:**
Slitting and cross-cutting of fiberglass insulation material, acoustical tile, flooring, and cove bases.
- **Dimensioned Stone Industry:**
Contour cutting of marble, granite, limestone, and other dimensioned stone.
- **Disposable Products Industry:**
Contour slitting of disposable diapers and hospital wear.
- **Electronic and Computer Industries:**
 - Contour cutting of printed circuit boards and membrane switches.
 - Removing flash from computer chip lead frames.
- **Food Processing Industry:**
Cutting, slicing and/or portioning of food products, such as fish, chicken, beef, olives, carrots, pizza, bread, and candy.
- **Glass Industry:**
Contour cutting of automotive window glass, stained glass, mirrors, glass table-tops, laminated glass.
- **Nuclear Plant Decontamination and Decommissioning**
- **Paper, Tissue, and Packaging Material Industries:**
 - Slitting and edge trimming of tissue, coated paper, foam board, linerboard, and corrugated boxboard.
 - Cleaning of heat-exchangers, lime kilns, liquor lines, and boilers.



Paper, Tissue, and Packaging Materials Applications. Waterjet Crosscutting of Web-fed Products. FLOW's CrossCutting Systems are used for a variety of web-fed products including paper, vinyl, rubber, and fiberglass insulation. Waterjets offer several advantages over conventional cutting systems for continuous web-fed applications: they are more accurate, create no airborne dust, reduce edge crushing and minimize jam-ups.



Paper, Tissue, and Packaging Materials Applications. Waterjet Slitting of Corrugated Boxboard. Compare the corrugated boxboard cut with a mechanical knife (left) with the boxboard slit with FLOW's waterjet (right). Waterjet slitting does not crush the flute, thus producing stronger boxboard. Alternatively, waterjet slitting enables customers to use lighter-weight paper and produce boxboard of equal strength. This crush-free feature is also important for other materials such as foam rubber and honeycomb composites whose edges are often crushed by mechanical slitters.



Paper, Tissue, and Packaging Materials Applications. Waterjet Slitting of Linerboard. This automated waterjet slitting system for linerboard is computer-controlled and can automatically reposition as many as 22 (8 shown here) waterjets simultaneously. FLOW designed both the hardware and the software for a complete turn-key system for this application.

• **Shoe and Garment Industries:**

Contour cutting of insoles, outsoles, leather uppers, fabric, and non-woven materials.

SOLUTIONS THROUGH TEAMWORK

FLOW has a worldwide network of OEMs, distributors, sales agents, and systems houses dedicated to the sales, integration and support of *FLOW*'s waterjet and abrasivejet systems for a variety of cutting and cleaning applications. These partners, together with *FLOW*'s Operations Centers in Seattle, Washington, W. Germany, and Taiwan, form a broad-based resource for solving customers' cutting and cleaning problems worldwide.

DEMONSTRATION, INSTALLATION, SERVICE, MAINTENANCE, AND TRAINING

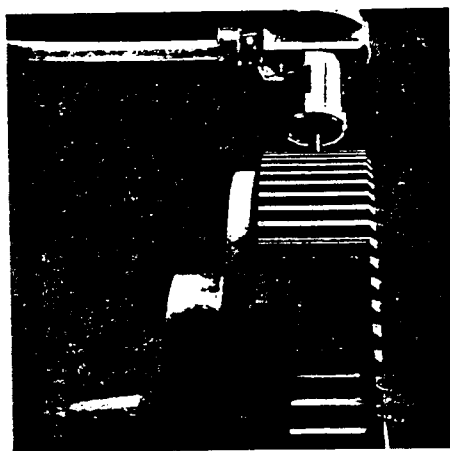
FLOW, with its affiliated waterjet cutting centers around the world, is available to DEMONSTRATE waterjet and abrasivejet cutting systems in a variety of applications.

FLOW offers turn-key INSTALLATIONS as well as on-site consultation and installation services to customers.

FLOW's SERVICE engineers are available in person from service centers worldwide and by telephone 24 hours a day. Replacement parts in specially designed protective packaging can be shipped for next-day delivery from *FLOW*'s inventory. *FLOW* can also refurbish many parts for extended use. Upgrades are designed to adapt to all previously purchased *FLOW* equipment.

FLOW offers PREVENTIVE MAINTENANCE programs to extend system life. Audit Service contracts provide maintenance consulting to customer personnel, Maintenance Service contracts provide maintenance by *FLOW* personnel, or *FLOW* can tailor programs to meet customers' specific maintenance needs.

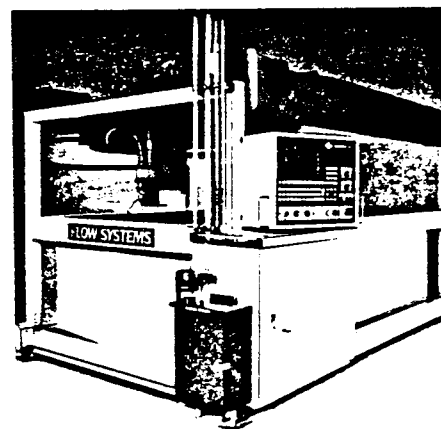
Operation and maintenance TRAINING courses are available at *FLOW* in Seattle and at customer sites. *FLOW* also offers professionally produced videotapes that give customers easy access to complete information about how to use and maintain their high-pressure systems for efficient and economical operation.



Equipment Manufacturing Applications. Abrasivejet Cutting of Transmission Gears. A major U.S. manufacturer of heavy earth moving equipment uses a *FLOW* abrasivejet in the manufacture of a transmission gear. The abrasivejet cuts a lubrication slot in the base of a gear tooth and eliminates a step in the machining processing, increasing productivity and reducing waste.



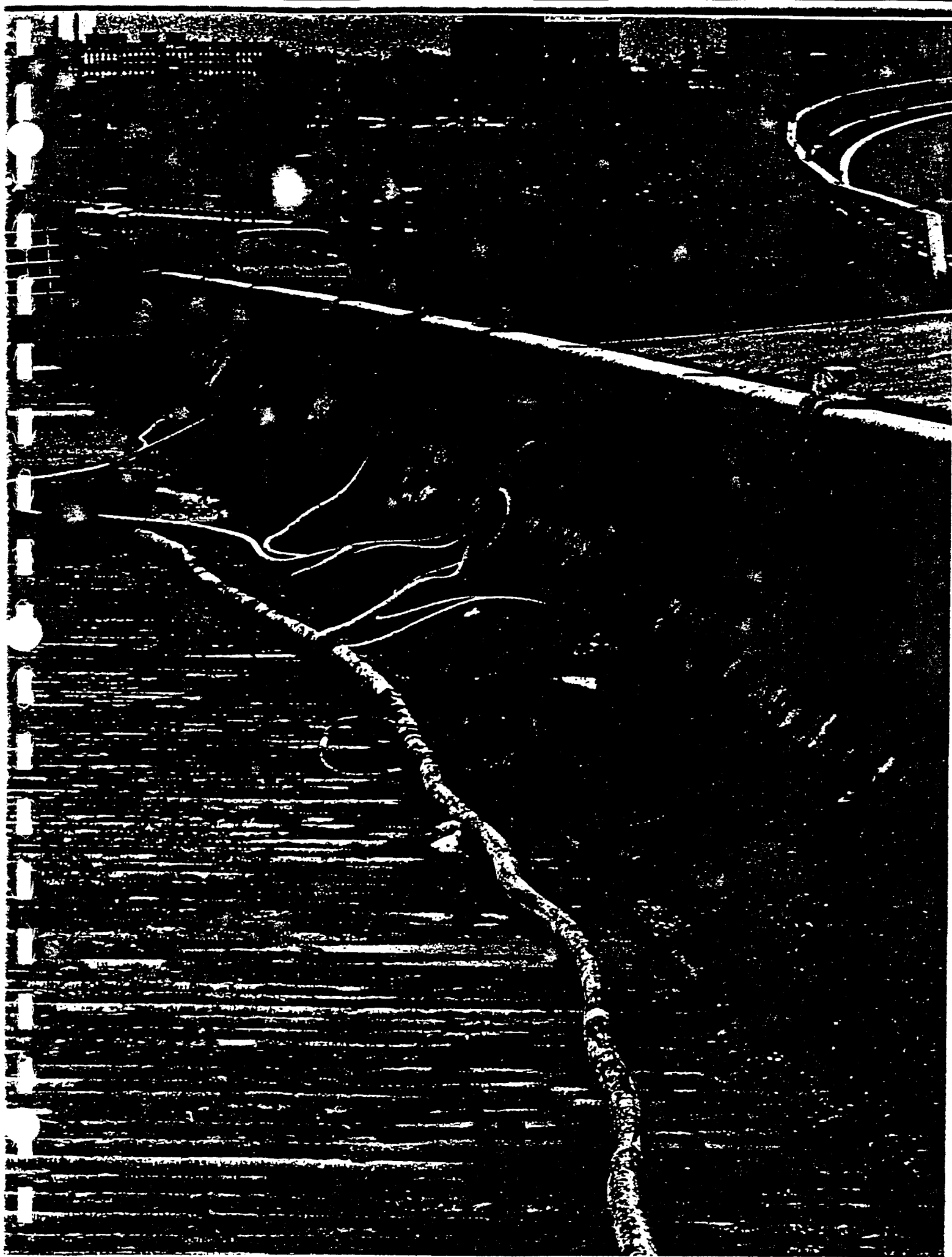
Disposable Products Applications. Waterjet slitting of diapers. Over 400 installations in 43 countries use *FLOW*'s waterjets to cut contour baby diapers and adult incontinence products. These installations typically operate 24 hours a day, seven days a week. *FLOW*'s intensifier pump, with 10 years of application experience, continues to establish itself as the pump of choice on diaper lines worldwide.



Shape Cutting Applications. Waterjet cutting of net shapes. *FLOW*'s TS net shape cutting system can cut heat sensitive metals and hard to cut materials like thick composites, ceramics, marble, granite, glass, etc. within .005 inches accuracy.

**FLOW
SERVICES
DIVISION**





THE BUSINESS

to provide ultrahigh-pressure (over 20,000 psi) waterjet and abrasivejet services for industrial cutting, drilling, milling and cleaning applications. The services established to date are:

- Hydromilling services in the U.S. and Canada to remove deteriorated concrete from highway bridges, parking garages, and other reinforced concrete structures.

- Machining services in the U.S. and Canada for industrial cleaning, cutting, and surface preparation with equipment rentals and contract services.

- Runway cleaning services in the U.S. through a joint venture partner.

- FLOW plans to develop joint venture partners around the world for:

- Hydromilling services
- Runway cleaning services
- Asbestos abatement services

FLOW Services Division provides hydromilling services, shown here and on the preceding page, that can remove concrete as fast as 15 jackhammers without damaging rebar. FLOW offers the service in the U.S. and Canada to remove deteriorated concrete from highway bridges, parking garages and other reinforced concrete structures.

HYDROMILLING SERVICES

FLOW has developed cost-effective ultrahigh-pressure waterjet systems for concrete removal. Using these systems, Flow Services Division offers hydromilling services on a subcontract basis in the U.S. and Canada to remove deteriorated concrete from highway bridges, parking garages, and other reinforced concrete structures.

FLOW's hydromilling systems operate in the pressure range of 25,000 to 35,000 psi. *FLOW* showed that waterjets begin to *cut* concrete at pressures over 25,000 psi, and was granted a method patent for waterjet cutting of concrete at pressures over 25,000 psi. Multiple ultrahigh-pressure waterjets, mounted on a high rpm rotating arm, are used to cut the concrete. For a concrete with given strength, the depth of cutting per pass can be controlled by adjusting for the proper pressure and traversing speed. Therefore, hydromilling of concrete offers precise depth control.

The Advantages of Hydromilling over Jack-hammering:

- **Fast.**

Hydromilling is a very efficient process for concrete removal. The concrete removal rate of a *FLOW* hydromilling system is equivalent to that of 15 jack-hammers. Typically, hydromilling can remove the deteriorated concrete from a

highway bridge or a parking garage 30 to 60 percent faster than jack-hammering. This significantly reduces the project construction time and cost.

- **Cost-effective.**

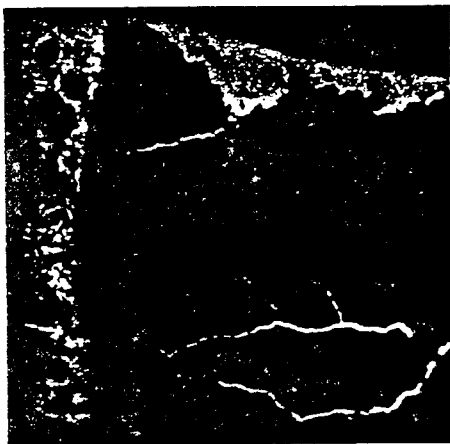
Hydromilling is a cost-effective concrete removal process.

- **Remove Less Concrete.**

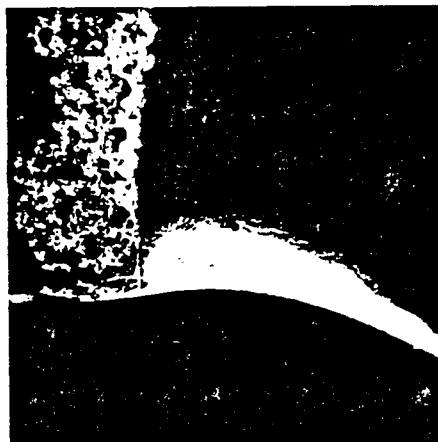
Jackhammer operators have difficulty differentiating good concrete from bad concrete and tend to overchip. Hydromilling significantly reduces this overexcavation. Ultrahigh-pressure waterjets cut away deteriorated and weakened concrete much faster and deeper than competent concrete. It is a "selective" milling process. Overall, hydromilling removes much less concrete and the repaving cost is lower.

- **No Micro-Cracks and Better Bonding.**

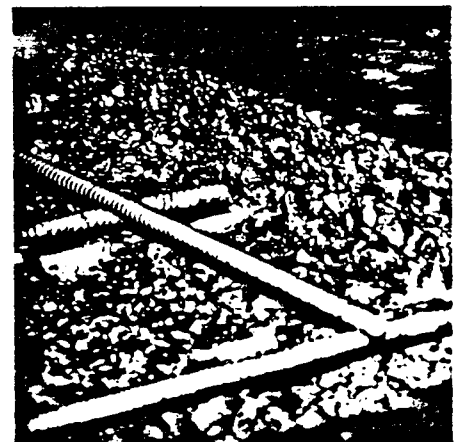
Jack-hammering develops micro-cracks in the concrete, resulting in poor bonding. Hydromilling does not develop micro-cracks in the concrete, and bonding results are excellent. In tests made by Concrete Technology Laboratories the bonding strengths of concrete paved over hydromilled surfaces were the same as the competent concrete.



Concrete Microstructure. Jack-hammering induces micro-cracks in concrete. These cracks result in poor bonding and reduce the service life of a new overlay.



Non-Destructive. Ultrahigh-pressure waterjets are non-destructive to surrounding concrete. The photo shows a crack-free concrete surface excavated by hydromilling.



Edge Cutting. *FLOW*'s hydromilling produces sharp, well-defined vertical edges. Secondary sawing is not required. The service life of a new overlay is extended.

- **Better Rebar.**

It is difficult for jackhammer operators to chip around the steel reinforcing bars without damaging them. *FLOW*'s hydromilling systems are designed in the pressure range that waterjets will cut concrete and remove the rust of the rebar without damaging the rebar. After a hydromilling operation, the rebar is exposed, cleaned of rust and corrosive material, and made ready for repaving without any secondary operations.

- **No Vibration, No Airborne Dust, and Less Noise.**

Jackhammer vibration is harmful to the operator and to the concrete structure and rebar; it generates a lot of airborne dust and is very noisy. *FLOW*'s hydromilling process greatly reduces the environmental impact. It has no vibration, is quiet enough for round-the-clock operations, and does not create airborne dust.

The Advantages of Hydromilling over Waterblasting:

Operating in the pressure range of 10,000 to 15,000 psi and with a high volume of water, waterblasting breaks up concrete, gets into the cracks and splits the concrete. Therefore, waterblasting is an uncontrolled demolition process, which removes bad as well as good concrete. The advantages of hydromilling over waterblasting are:

- **Remove Less Concrete.**

Hydromilling provides precise depth control and removes less concrete. Therefore, it costs less to repave.

- **Use Less Water.**

Ultrahigh-pressure waterjets use small amounts of water.

- **Debris Control.**

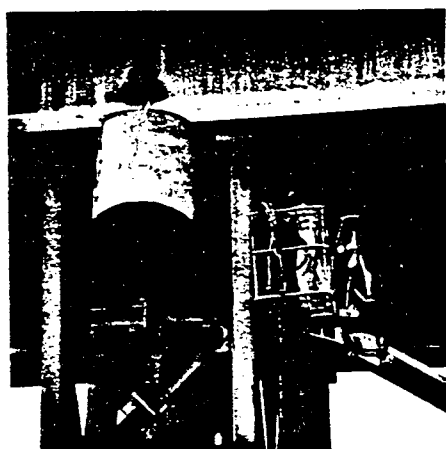
Waterblasting breaks away large pieces of concrete, and the concrete removal operation has to be totally enclosed. On the other hand, ultrahigh-pressure waterjets cut concrete to small pieces, and the debris can be shielded and vacuumed away. For a given interstate bridge hydromilling job, two lanes of the bridge are open to traffic, while the other two lanes are being hydromilled.

- **No Shadows under the Rebar.**

Unlike waterblasting, *FLOW*'s ultrahigh-pressure rotating waterjets can effectively remove the concrete under the rebar and do not leave any shadows which would require hand-chipping.

- **Sharp Edge.**

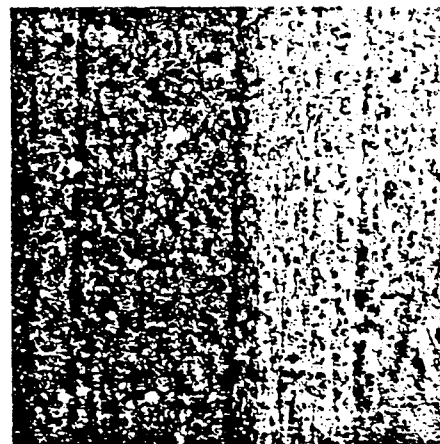
Ultrahigh-pressure waterjets cut the concrete and provide a well-defined edge.



Concrete "Dental Work." *FLOW*'s hand-held waterjet tools are easy to use in difficult working conditions. This rotary JetLance performs "dental work" on a deteriorated bridge support beam.



Cutting and Drilling of Concrete. *FLOW*'s ultrahigh-pressure waterjet cuts precision grooves as well as holes for rebar into this bridge girder.



Laitance Removal from Concrete Surface. *FLOW* has a laitance removal system that can strip laitance away from concrete with speed and precision, leaving a clean bonding surface, as illustrated on the left side of the photo.

JETTING SERVICES

FLOW SERVICES DIVISION provides ultrahigh-pressure jetting services for a variety of industrial cleaning, cutting, and surface preparation needs, through equipment rentals or contract services.

These ultrahigh-pressure waterjet tools are coming to market at a time when many traditional cleaning tools are found to be inadequate, expensive to operate, or environmentally unacceptable.

FLOW's ultrahigh-pressure jetting tools operate in the pressure range of 25,000 to 40,000 psi, generating high velocity waterjets at speeds over 2,000 feet per second.

The Advantages of Ultrahigh-pressure Jetting over Conventional Cleaning Methods (such as Mechanical Cleaning, Chemical Cleaning, Sandblasting, and Waterblasting Methods):

- **Complete Surface Preparation.**

It completely removes old and defective coatings, deposits, rust, etc. It cleans steel surfaces to the bare metal.

- **Low Thrust.**

Unlike waterblasting, hand-held ultrahigh-pressure waterjet tools generate very small thrust and are much less tiring for the operator.

- **No Hazardous Chemicals.**

Ultrahigh-pressure waterjet uses water only, no hazardous chemicals.

- **Less Water.**

Unlike waterblasting, *FLOW's* ultrahigh-pressure waterjet uses very small amounts of water. It reduces the cost of water and the problem of waste water disposal.

- **No Airborne Dust.**

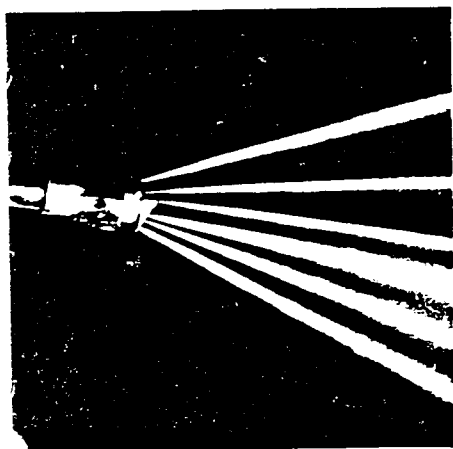
Unlike sandblasting, ultrahigh-pressure waterjets create no airborne dust.

- **Does not Damage the Surface.**

Unlike mechanical brushes or chisels, ultrahigh-pressure jetting does not damage the surface or deform the bond profiles.

- **Remote Control.**

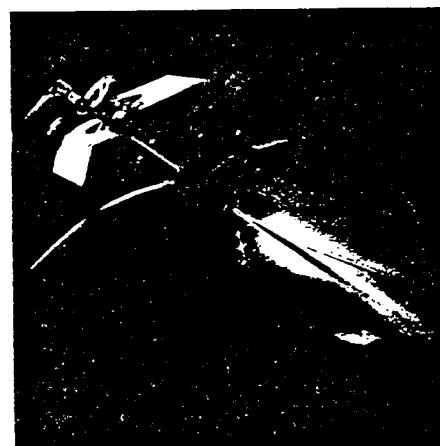
Ultrahigh-pressure waterjets generate very small thrust and thus are easily integrated with robots to handle precision cleaning of auto body-carriers as well as hazardous jobs such as decontaminating or decommissioning work in nuclear power plants.



FLOW's Rotary Waterjet is a very efficient tool for cleaning fouled heat exchanger tubes. Even the hardest residues and deposits are completely removed, restoring tube surfaces to their original condition, improving thermal efficiency, and lowering production and generation costs.



FLOW's Lightweight JetLance brings portability to ultrahigh-pressure waterjet technology. The tool features up to eight waterjets rotating at 2,000 rpm. The pressure and velocity of the jetting streams are adjustable, making the tool adaptable to surface preparation work of almost any kind, from removing hard deposits to cleaning priceless bronze statues.



Abrasivejet Cutting of Steel Pipe. When abrasives are entrained into the ultrahigh-pressure stream, the waterjet can cut virtually any substance — even tool steel — without heat build-up. In the photo, a *FLOW* abrasivejet cuts a 3 ft. diameter steel pipe. There is no metallurgical change along the edge because there is very little heat generated in the cutting process.

used in its removal, including water, must be packaged and taken to an approved hazardous waste disposal site. Because waste volume is a major cost component of this procedure, conventional high-volume waterblasting is unacceptable. *FLOW's* solution to this problem is low-volume ultrahigh-pressure waterjets delivered from a lightweight hand-held tool. The resulting jet thrust is so low the operator hardly notices it, but the cutting and cleaning power of the tool is extraordinary. Multiple, fast-rotating waterjets rapidly remove the asbestos-containing material, peeling it from structural components and thoroughly cleaning the underlying surface in a single operation. Even the smallest pores and crevices of the substructure are totally cleaned and freed from any remaining asbestos fibers. *FLOW's* ultrahigh-pressure waterjets significantly increase the productivity, that is, more square feet cleaned per man-hour, and reduce the waste disposal costs.

- **Ships and Submarines.**

FLOW's ultrahigh-pressure waterjets can remove all the marine growth and rust from the ship hull in a single operation. They are used onboard ships and sub-

marines to remove paint and rust for re-coating, to remove anti-skid coating on decks, to cut metal pipes, tanks, and structures.

- **Restoration of Statues.**

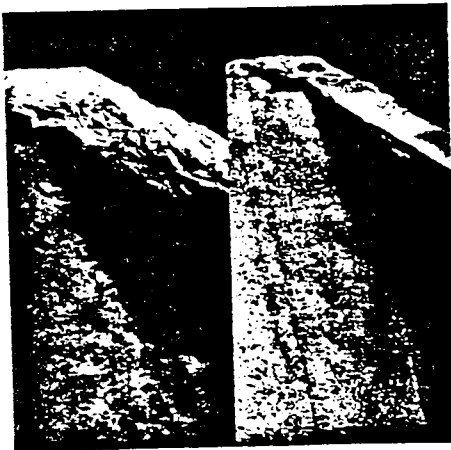
The pressure and traversing speed of *FLOW's* ultrahigh-pressure waterjets can be adjusted so precisely that they will remove the oxidations from metal statues without damaging the surface. *FLOW's* waterjets were used to restore the William Penn bronze statue above Philadelphia's City Hall.

- **Offshore Oil Platforms.**

Operators of offshore oil rigs find *FLOW's* ultrahigh-pressure waterjets to be a very cost-effective way to remove the paint and rust and to cut. They also find that the use of abrasivejets to cut metal structures can eliminate the fire hazard of using a torch.

SERVICES IN THE UNITED STATES AND CANADA

FLOW SERVICES DIVISION provides ultrahigh-pressure jetting services in the United States and Canada from four Sales Offices and three Service Centers. *FLOW* is committed to quality services.



Removal of Mineral Deposits. Hard mineral deposits on this steel surface were removed quickly, without cutting or scraping. The process took only 30 percent of the time required by conventional methods.



Cleaning of the William Penn Bronze Statue. The statue, standing above Philadelphia's City Hall, is shown before and after cleaning by *FLOW's* ultrahigh-pressure waterjets. The power of these tools can be fine-tuned to protect delicate surfaces.

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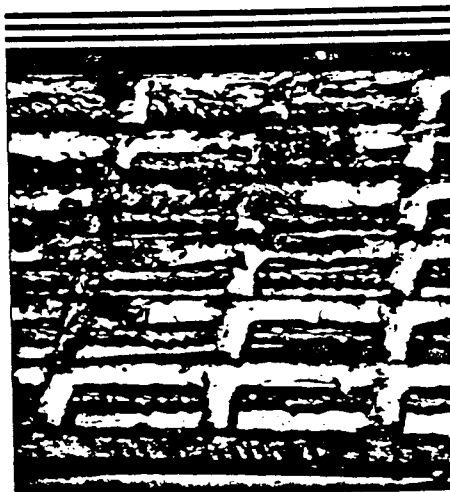
Tel: 314-962-8855

Ultrahigh-pressure water strips away built-up coatings fast

A Jetlance™ ultrahigh-pressure water cleaning system from Flow International Corporation (FLOW) quickly cleaned coating build-up from auto carriers and paint booths without fumes or damage to the structures or surfaces. The hand-held Jetlance™ stripped away even tough-to-remove primer and ClearCoat better than previously used methods.

Above: Before cleaning (left). After cleaning (right).

APPLICATION PROFILE: Auto Carrier Cleaning



A major automobile manufacturer applies today's extremely durable-bond multi-coat finishes to automotive components and bodies. To do this, the company uses dip tanks, automated robotic sprayers, aerial and floor chains, component carriers and other aids.

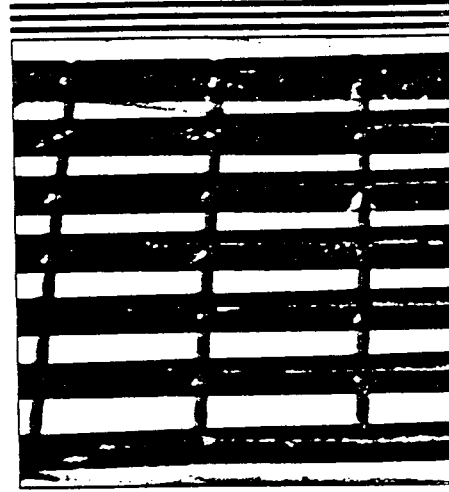
The Problem

Unfortunately, the coatings bond to the chains and carriers as firmly as they bond to the painted components. Coating build-up eventually interferes with carrier alignment, which in turn interferes with the guidance system of the robotic paint-sprayers. Traditional cleaning techniques such as thermal treatment, solvent stripping, and low-pressure, high-volume waterblasting all have major disadvantages.

Thermal treatment was expensive because of fuel and emission control costs. Thermal treatment often failed to clean completely, and heat damage frequently occurred to the parts being cleaned.

Solvent stripping was expensive because of the cost of solvent, solvent disposal, emission control, and worker protection. Solvent stripping was often ineffective because many of the new coatings are resistant to it.

Low-pressure, high-volume waterblasting was an improvement over the thermal and solvent methods,



but waterblasting was inefficient and costly because of the large volumes of waste water that had to be treated before disposal.

The company needed an economical and efficient way to clean auto carriers and paint booths without damaging its equipment.

The Solution

A hand-held Jetlance™ delivering up to 2.4 gpm of 35,000 psi water through nozzles rotating at 1200 rpm quickly strips away built-up coatings of all types without damage to the chain-carriers or booth walls.

Using a Jetlance™ conveniently suspended from a tool balance, operators are able to remove even tough coating build-ups such as ClearCoat and primer from hard-to-reach places. Designed for use with FLOW's Jetpac™ series of variable displacement, ultrahigh-pressure intensifier pumps, the Jetlance™ uses a power takeoff from the Jetpac™ to drive the rotating nozzle.

Clean carriers reduced the components reject rate, and Jetlance™ cleaned carriers were returned to service without expensive repairs. The ultrahigh-pressure, low-volume waterjet system saved thousands of dollars in fuel emission control costs. The light weight and low thrust of the

(Continued)

Jetlance™ made it easy for operators to handle, and its speed and efficiency saved labor costs.

Best of all, the Jetlance™ system costs less to install and is more economical to operate and maintain than cleaning ovens and quickly pays for itself with immediate savings in energy and capital equipment repair costs.

Benefits

- Low cost
- Easy waste disposal
- Labor savings
- Cleans to bare metal
- No structural or surface damage

FLOW Equipment Used

Jetpac™ Model 40 EDX intensifier pump (2.4 gpm @ 35,000 psi)

Jetlance™ Model 5050

Tool balance

Related Applications

- Gratings, emission stacks, and paint drain tubes and fans
- Surface decontamination
- Rust removal
- Scale and biogrowth removal



Flow International Corporation is the world leader in ultrahigh-pressure waterjet and abrasivejet technology for industrial cutting and cleaning.

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Jetpac™ Intensifier Pump— Model 40DT

The Model 40DT, a portable or stationary intensifier pump, is the industry standard for ultrahigh-pressure waterjet cleaning and cutting applications. The 135 hp [100 kw] diesel engine-driven hydraulic pump and four intensifiers have enough power to supply multiple hand tools or one of Flow International Corporation's (FLOW) specialized cleaning and cutting systems. Low water consumption saves money on water supply and disposal costs, and the low flow rates produce low thrust for hand-held tools. Long-wearing parts ensure the longest life and highest reliability available for waterjet applications. The air-cooled Deutz diesel engine offers many hours of trouble-free operation.

Features

- Design pressure 40,000 psi [2,700 bar]
- Maximum recommended continuous operating (dynamic) pressure under production conditions: 35,000 psi [2,400 bar]
- Hydraulic Power Takeoff: Two PTOs provide up to 6 gpm [21 lpm] at 1,500 psi [103 bar]. Outlet configurations allow operation of either one or two hydraulic tools
- Automatic shut down for low hydraulic oil level, high hydraulic oil temperature or low inlet water pressure
- Automatic water pressure bleed-down valve
- Inlet water booster pump for both intensifier supply and cooling water requirements
- Rugged steel frame with removable cover panels for easy maintenance
- Service Tool Kit

The FLOW Edge

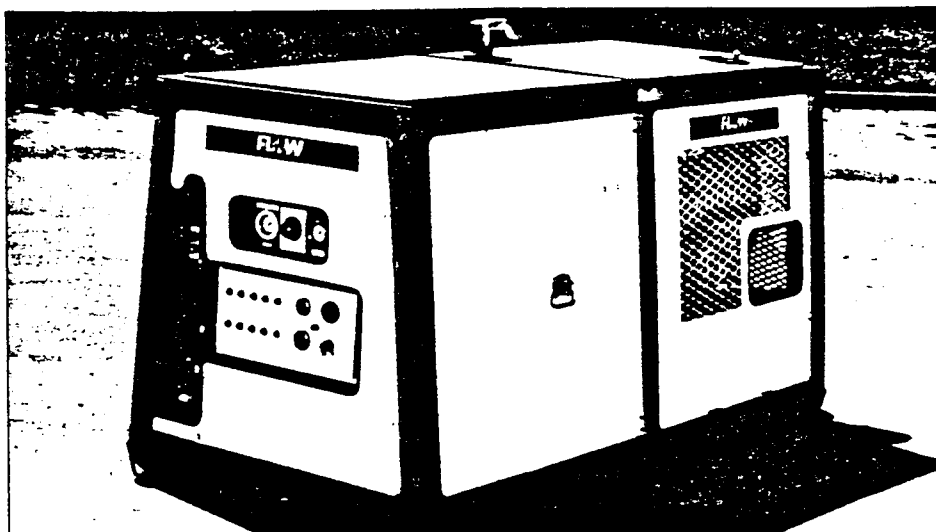
Performance. FLOW's Jetpac™ intensifier pumps provide excellent performance by minimizing pressure dips (negative spikes) caused by intensifier shifting. With

FLOW's ultrahigh-pressure intensifier pumps, smaller nozzle sizes and lower water flow rates can do a superior job. Fatigue of high-pressure tubing, high-pressure hose, valves, swivels, and nozzles has been reduced to a minimum.

Pressure Quality. Jetpac™ intensifier pumps deliver consistent pressure at the nozzle independent of the water flow rates required. When varying nozzle combinations or conditions change your flow demands, the Jetpac™ intensifier pump will automatically supply the same pressure without readjustment. This gives you superior flexibility.

Exclusive Alloy Plunger. The design and unique metallurgical properties of our alloy plunger, manufactured exclusively for FLOW, extend both seal and plunger life for maximum equipment productivity.

Safety. Rupture disks are not required for safe operation, which eliminates unscheduled equipment shutdowns because of rupture disk malfunctions. Our high-pressure attenuator is TUV-approved for conformance to the highest quality design and safety standards.



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(Continued on page 2)

Lower Energy Costs. Efficient design means Jetpac™ intensifier pumps require less horsepower to handle your job.

Ease of Maintenance. High-pressure components of Jetpac™ intensifier pumps do not require daily greasing. The modular intensifier pump design allows the

most convenient maintenance scheduling for minimal station down-time.

Experience. Worldwide, FLOW intensifier pumps have logged more than 20,000,000 operational hours of waterjet and abrasivejet cutting and cleaning.



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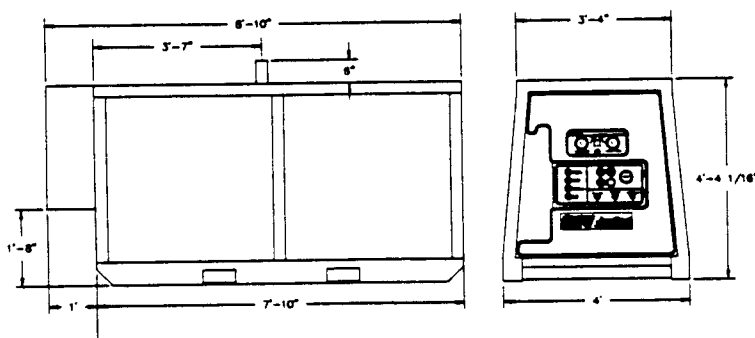
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Equipment

Pumped Medium: Water*
Intensifier:

Type Double Acting
Type of Shift Mechanical

Hydraulic Pump:

Displacement 7.2 in³ [118 cm³]
per revolution
Type Denison axial piston,
closed loop, pressure
compensated
Number of pumps One

Hydraulic Oil Reservoir:

Capacity (approx.) 25 gallons
[94 liters]

Hydraulic Oil Filtration:

Micro-filtration .. 10 micron absolute

Hydraulic Oil Cooling System:

Type .. Oil to water heat exchanger

Cooling Medium Water
Cooling Water Flow Rate 6 gpm
Thermostat controlled [22 lpm]

Attenuator Size: 124 in³ [2030 cm³]

Operating Sound Level: 95 db (A)
(measured at 3m under anechoic
conditions)

Performance

Maximum Continuous Operation:
Intensifier Pressure (psi) [bar] 35,000
[2,400]

Number 3
Ratio 13:1
Output flow rate (gpm) [lpm] 4.0 [15]
Weight (without fluids) 5,065 lbs
[2,297 kg]

Engine:

Manufacturer Deutz
Horsepower (hp) [kw]** 135 [100]
Cooling Air
Engine type 6 cylinder, turbo-charged, 4-cycle direct injected
Speed (rpm) 2,300

*Water to be filtered and pH-adjusted for best performance. If medium other than water is used, contact Flow International Corporation.

** Horsepower is rated from sea level to 4,000 feet [1219 m] above sea level. For applications at higher elevations or temperatures >95°F, contact Flow International Corporation.

Jetlance™ Model 5050

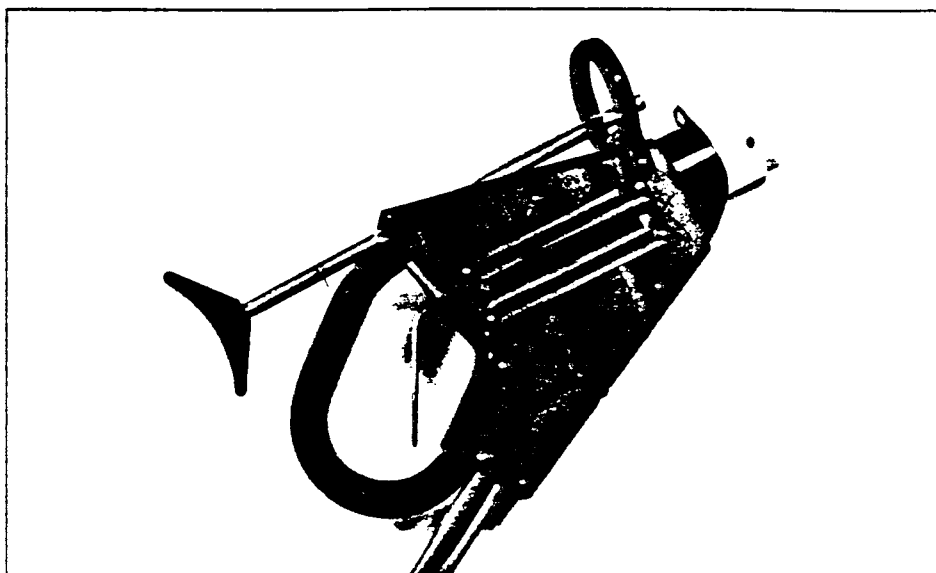
Flow International Corporation (FLOW) offers a hand-held cleaning tool that uses ultrahigh-pressure water to clean tough-to-remove materials from a variety of surfaces.

Applications

The Jetlance is a hand-held, multi-purpose area cleaning and material removal tool. Tips with multiple orifices at various angles rotate at up to 2,000 rpm while delivering up to 5.6 gallons per minute of water at 35,000 psi — truly ultrahigh-pressure water.

These multiple jets of ultrahigh-pressure water moving at over 3,000 feet per second turn the Jetlance into a high-energy-density cutting tool that removes hard, tough materials. Epoxies, resins, rust, rubber lining, calcium deposits, oxides, concrete, and other materials that formerly had to be removed by burning, sand-blasting, mechanical action, or chemicals can now be removed using only ultrahigh-pressure water.

The Jetlance is also useful for decontamination applications — removing hazardous chemical or radioactive materials. The combination of low volumes of ultrahigh-pressure water and true cutting power produces better control and easier hazardous waste disposal.



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Features

- Tip rotation is adjustable from 0 to 2,000 rpm maximum.
- On/off valve produces instantaneous ultrahigh-pressure water.
- Oil hydraulic power from the Jetpac PTO (Power Take Off) produces the rotation.
- The Jetlance comes equipped with an 8-jet tip and a 8-foot whip hose set.

Optional Accessories

- Turn the Jetlance into a Jetlance System with the addition of an Accessories Package, consisting of 2-foot and 3-foot extensions, spare parts kits for Swivel and On/Off Valve, and a variety of 2- and 4-jet tips and shrouds.

(Continued on back)



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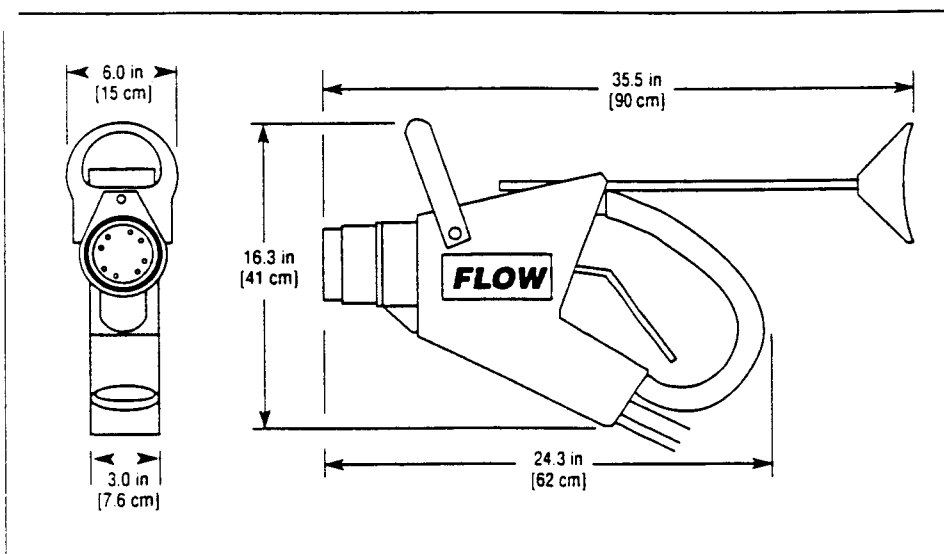
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Specifications

Maximum Operating Pressure

35,000 psi

Weight

30 lbs with Whip Hose Set

Hydraulic Oil Requirement

2.75 gpm at 1,500 psi

Ultrahigh-pressure Water Delivery Capability

0-5.6 gpm at 35,000 psi

Jetwand™ Model 5013

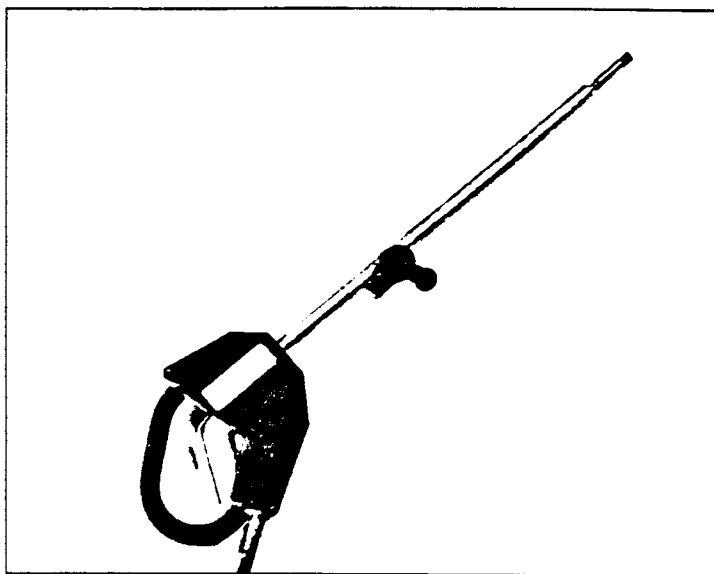
Flow International Corporation (FLOW) offers a hand-held tool that uses ultrahigh-pressure water for removing tough coatings from surfaces and for concrete demolition applications.

Applications

The Jetwand is a hand-held, lightweight tool for cutting and removing tough coatings from surfaces and for demolition applications requiring a single jet of high-energy density. The Jetwand will selectively excavate concrete from rebar without structural damage in the 2-5 ft³/hour range, depending on the state of the concrete.

With the addition of an optional abrasivejet nozzle, the Jetwand System will cut tough epoxies, reinforced concrete, rock, glass, steel, alloys, refractories, and composite armor — materials that up to now had to be removed by heat, chemicals, or mechanical action.

Operating at pressures up to 35,000 psi, the Jetwand produces excellent cutting power and its low flow rate produces low thrust, making the Jetwand easy to control.



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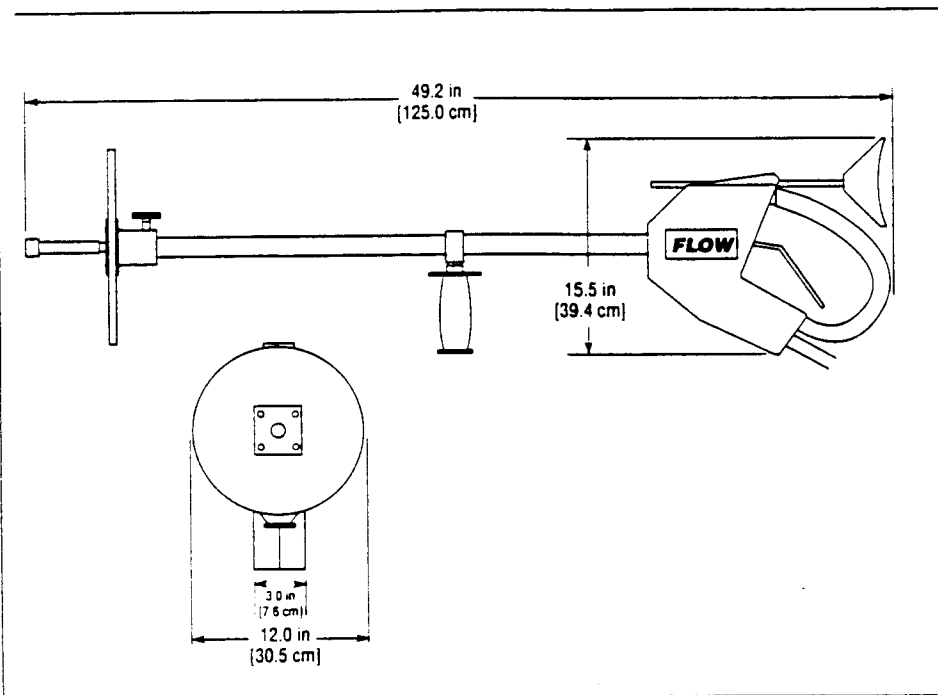
Features

- On/off valve produces instantaneous ultrahigh-pressure water.
- The Jetwand comes equipped with a waterjet tip, a 3-foot stem, and a protective shield.

Optional Accessories

- Turn the Jetwand into a Jetwand System with the addition of an Accessories Package, consisting of a selection of waterjet nozzles and accelerator tubes to fit a variety of abrasivejet cutting and wet sandblasting needs, and spare parts kits for the Swivel and On/Off Valve.
- For abrasivejet cutting, an abrasive hopper holding 250 lbs of abrasive material includes a metering orifice to control abrasive flow at 1-6 lbs per minute.

(Continued on back)



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Specifications

Maximum Operating Pressure

35,000 psi

Weight

16.5 lbs



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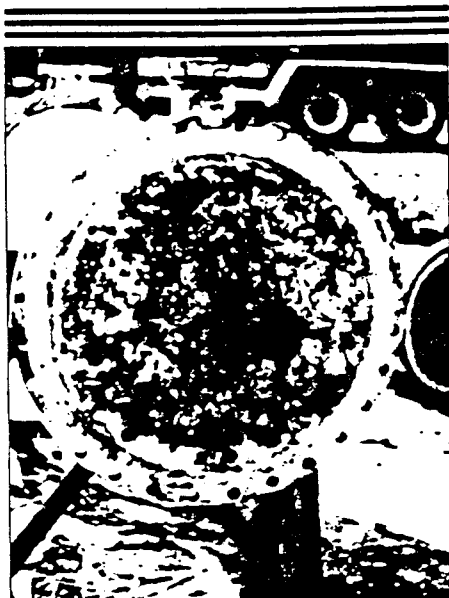
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Heat Exchanger Tubes Cleaned to Bare Metal.

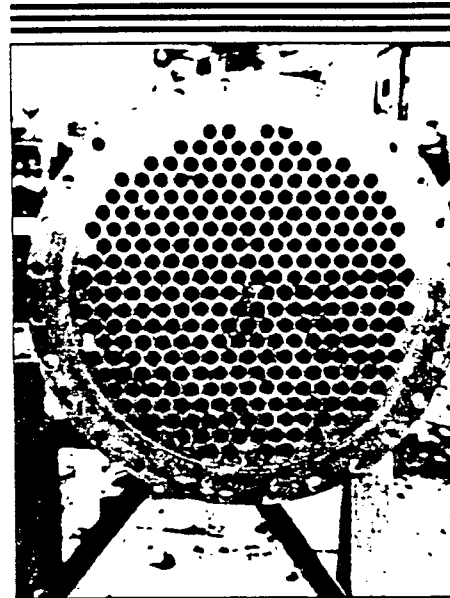
A 35,000 psi waterjet saves bundles.

The Flow International Corporation (FLOW) ROTOJET TRAC™ ultrahigh-pressure waterjet cleaning system surpasses all traditional methods of cleaning and reconditioning heat exchangers and other tubular structures. The ROTOJET TRAC™ system cuts fuel costs once tube bundles are "like new" again. Plant managers are pleased with the results: heat exchangers are in service longer, tube bundles aren't damaged or partially cleaned by less-effective methods, and heat transfer is restored to original rates.

APPLICATION PROFILE: Cleaning Heat Exchangers



(Before cleaning) Encrusted tube bundles can no longer function efficiently in this heat exchanger.



(After cleaning) 35,000 psi waterjet cleaned these tube bundles to a bare-metal finish.

The Problem

Heat exchangers collect process residue and scale inside their tube bundles as chemicals and chemical by-products flow through them. Unwanted build-up can consist of vinyl chloride monomer, polyurethane, polypropylene, coke, butyl rubber, automotive paints and primers, acrylic plastics, water scale, and crude oil residues.

Over time, the heat exchanger becomes less efficient as the build-up reduces product throughput and heat transfer, and increases fuel costs.

Typically, the encrusted metal tubes have never been cleaned to their original grey-metal finish. In some cases, the tubes become so blocked, plant managers must consider replacing them. Conventional cleaning methods such as acids, chemicals, and mechanical drilling cannot always safely produce a 100% clean surface. In fact, these methods often damage the tubes and cannot be used more than once.

The Solution

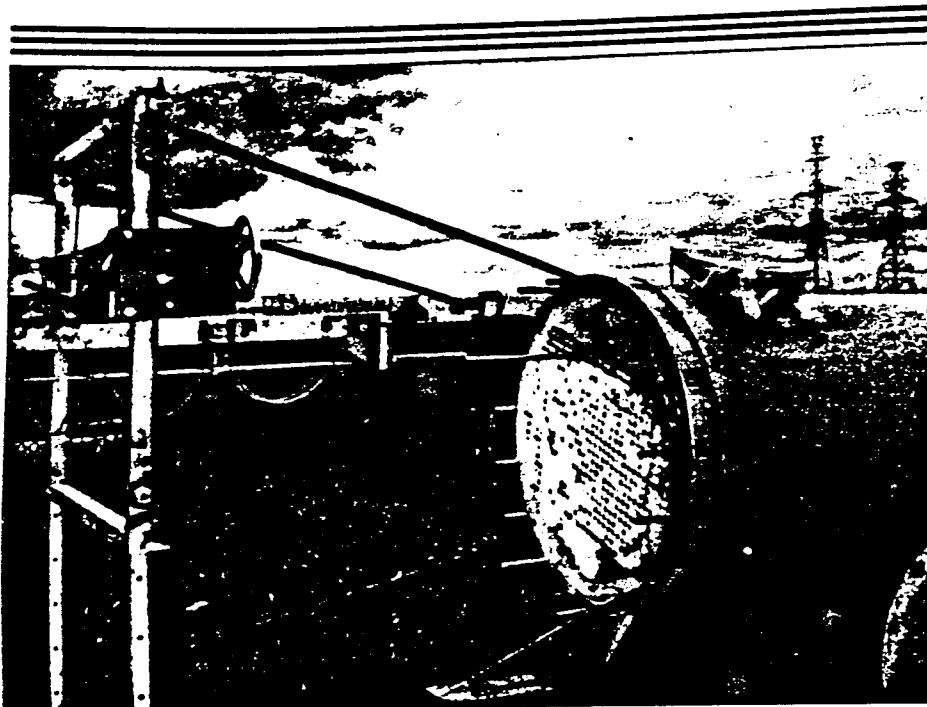
FLOW's 35,000 psi waterjet cleaning system, consisting of a diesel-powered 40,000 psi, 3.6 gpm intensifier pump and a semi-automatic ROTOJET TRAC™.

The ROTOJET TRAC™ opens and cleans away blocking residue from each individual tube, producing a "like-new" metal finish. Multi-jet tips rotating up to 500 rpm thoroughly clean and polish tube surfaces. The lance stem that carries the multi-jet tips can be lengthened or shortened to fit any tube length.

Flexible cleaning stems can be mounted onto the unit, enabling it to operate at various angles to the bundle axis. The flexible stems can also be used to clean curved tubes and tube bundles in difficult-to-reach locations.

The ROTOJET TRAC™ effectively restores heat exchangers to full operating efficiency, reduces fuel costs, and extends the useful life of tube bundles.

(Continued on back)



Closeup view of ROTOJET TRAC™ in operation.

Benefits

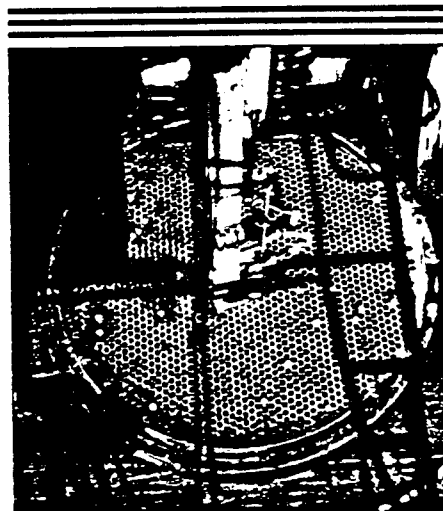
- Removal of deposits other processes leave behind
- Return to original heat-transfer efficiencies
- Heat exchangers in service for much longer periods
- No damage to tube walls
- Adaptable to a variety of tube sizes and configurations

FLOW Equipment

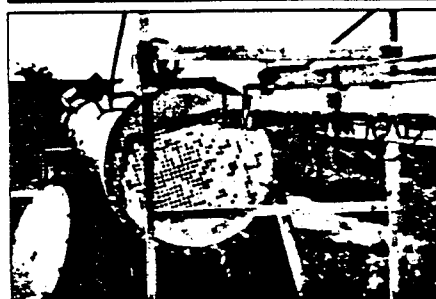
- 1 ea. — Triple intensifier pump (3.6 gpm at 40,000 psi)
- 1 ea. — ROTOJET TRAC™ cleaning system

Related Applications

- Pipe cleaning
- Cylinder cleaning
- Rocket motor recycling
- Non-abrasive surface cleaning and preparation



Vertical cleaning



Horizontal cleaning



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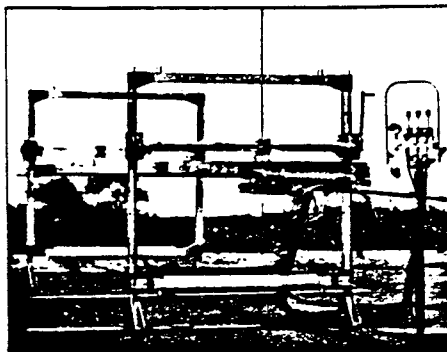
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ROTOJET TRAC™ SYSTEM

The ROTOJET TRAC™ system from Flow International Corporation (FLOW) quickly and efficiently cuts away residues from the interior surfaces of tubes and pipes as small as 1/2" ID.

This versatile system uses ultrahigh-pressure, multi-nozzle waterjets, rotating at up to 500 rpm thoroughly cleaning heat exchanger tube bundles. Even completely blocked tubes can be restored to like-new efficiency.

FLOW SPECS



Applications

FLOW's ROTOJET TRAC™ system is the most efficient and effective way to clean blocked or heavily encrusted heat exchanger tubes. The ultrahigh-pressure, rotating waterjets of actually cut away residue to the bare metal. Tube bundles scoured by the ROTOJET TRAC™ often perform as well as they did when they were new.

Ultrahigh-pressure (35,000 psi [2400 bar]) waterjet cleaning techniques extend the useful life of tube bundles previously cleaned and etched by chemicals or acids, without damaging the tube walls. And unlike most mechanical tube cleaning systems, the ROTOJET TRAC™ can be lengthened or shortened to accommodate the length of tubes to be cleaned.

From a remote control panel, an operator can advance the cleaning stem at its most efficient cleaning speed, and vary the retraction rate. Thrust of the cleaning stem is adjustable, with an adjustable slip clutch to prevent overloads.

The remote controls also govern ultrahigh-pressure water flow and stem rotation. Stem height and lateral traverse are easily adjusted for tube indexing. This lightweight system is easy to set up on decks or temporary platforms.

Features

The ROTOJET TRAC™ is designed for use with FLOW's

Jetpac™ series of variable displacement, ultrahigh-pressure pumps that provide hydraulic oil power takeoffs to operate the drive motors of the system.

- Length-of-travel: available in 5-foot increments
- Remote controls
- Adjustable rotation speed
- Adjustable advance, thrust, and retraction
- 30-foot (9.14-mm) hydraulic fluid hose bundle
- 3/8" and 9/16" OD high-pressure lance stems with couplings
- Assortment of cleaning tips with 2-, 3-, 4-, and 5-jet nozzles

Specifications

Maximum Operating Pressure

35,000 psi [2400 bar]

Water Flow Rate

Water flow rate will vary as a function of the nozzle orifice size and operating pressure. The ROTOJET TRAC™ will work with Models 40EDX, 40DT, and 40DQ.

Hydraulic Oil Requirement

6.5 gpm [24.6 lpm] at 1,500 psi [100 bar]

Stem Rotation

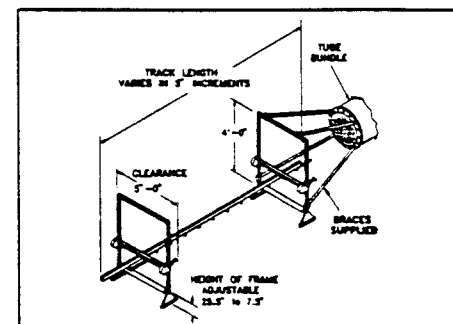
50-500 rpm

Speed Range

12-100 ft/min [3.7-30.5 m/min]

Weight

350 lbs [159 kg] with Hose Bundle for 20-foot (6.1-m) travel. Add 30 lbs [14 kg] for each additional 5 feet [1.5 m] of travel. *Individual components weigh less than 60 lbs.*



Cleaning Rate

Cleaning rate is dependent upon the nature of the material being removed, water pressure, and

nozzle orifice size. Test cleaning data are available from your FLOW representative.



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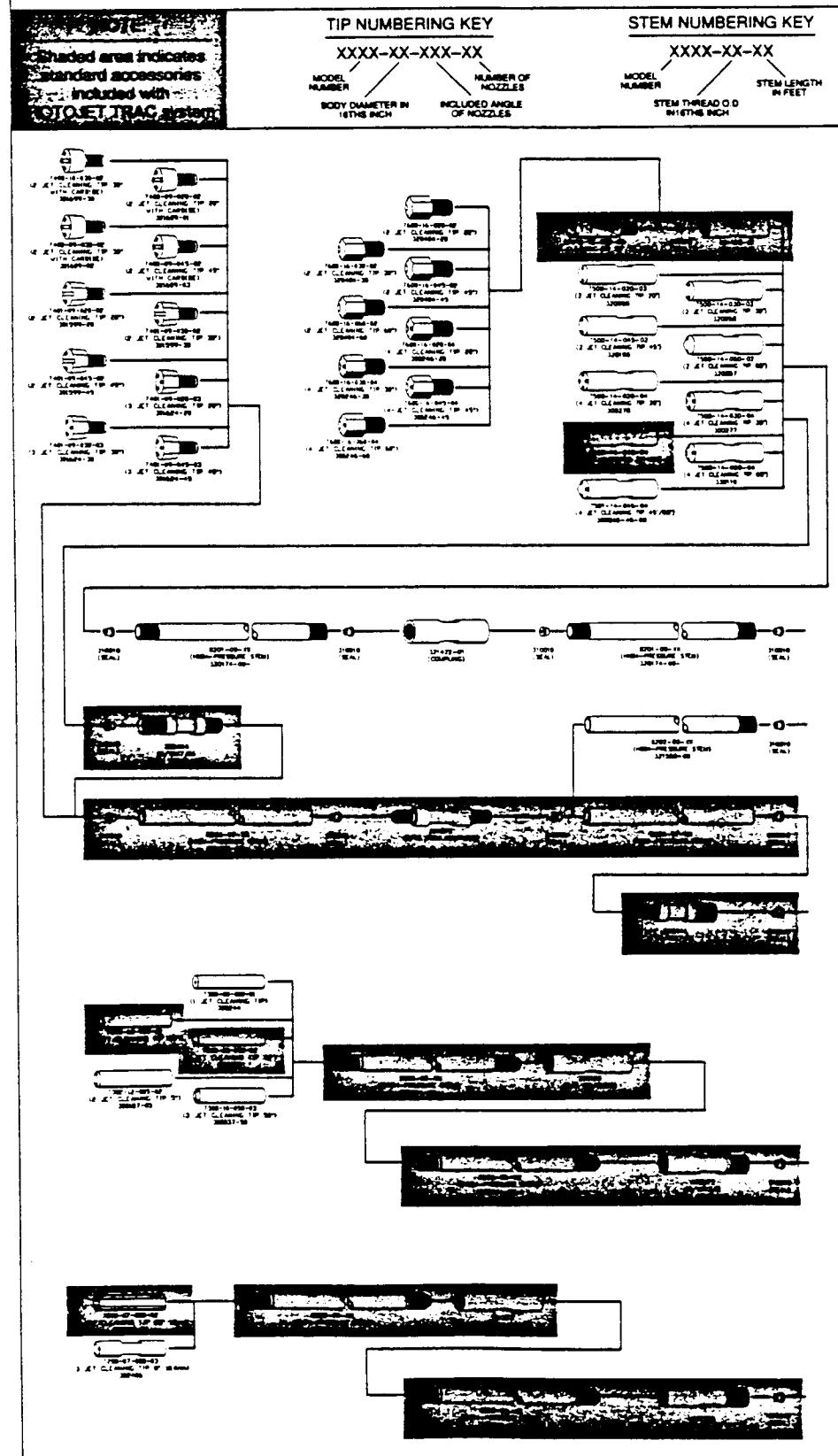
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Accessory Kit — 6110 Rotojet



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ENGINEERED ROBOTIC SYSTEMS

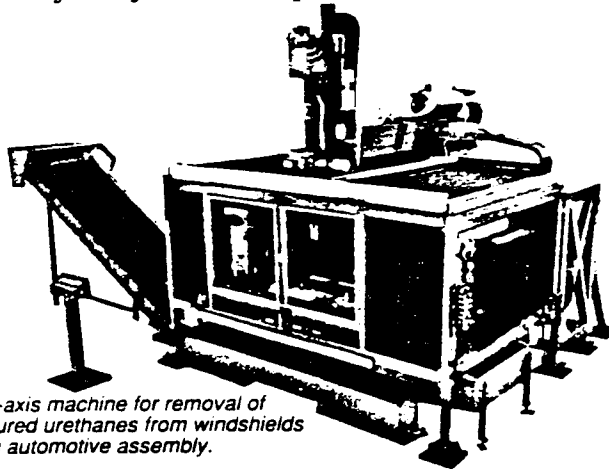


ACCURATION

Keeping Pace With Demand

ASI Robotic Systems offers a complete line of programmable robotic systems for industrial applications. Water jet cutting, laser work, grinding, dispensing, bonding, machine tending and pick-n-place material handling are some of the more popular uses for these versatile machines. Manufacturing today demands a high degree of accuracy and repeatable motion control for assembly and transfer lines, and in other automated production.

To keep pace with this demand, ASI has responded with robotic systems engineering for fast, reliable motion control in assembly and process operations which call for precision as well as speed. Due largely to the heavy-duty, beefed-up construction of ASI



5-axis machine for removal of cured urethanes from windshields in automotive assembly.

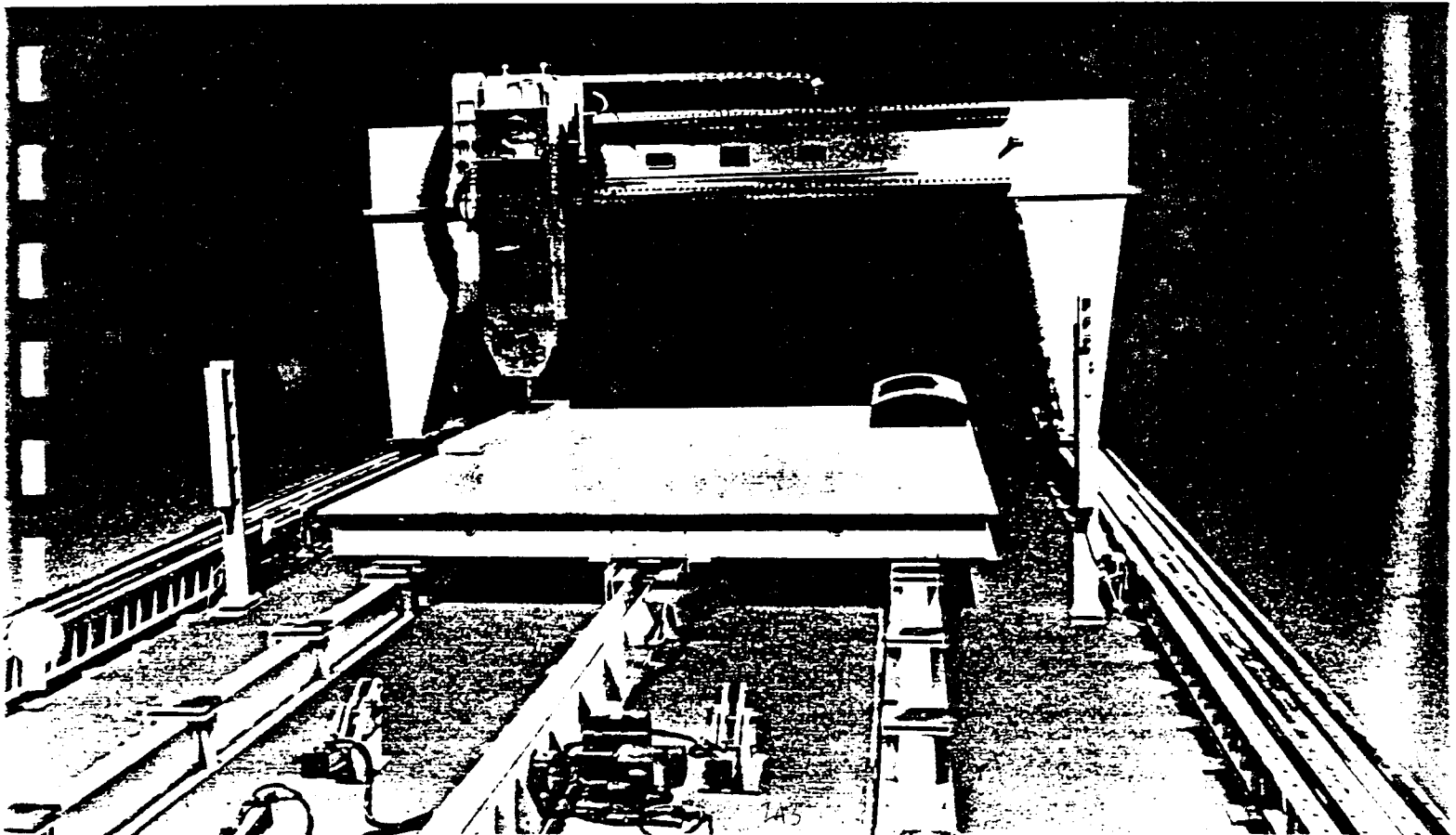
machines, our systems excel at both. Tolerances can be held to within 0.005" variation in most applications. Cycle times are measured in fractions of a second.

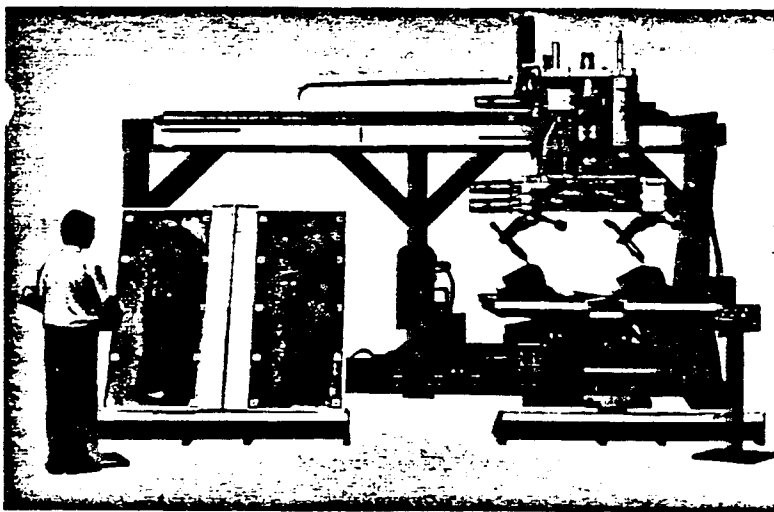
Engineered For Volume Production

Designed for heavy-duty, high-volume work in factory environments, ASI robotic systems are constructed for maximum rigidity and consistent, repeatable performance. Systems can be sized with work envelopes to handle even the largest components. Automakers, for example, use ASI dispensing robots to bond and seal decks, hoods, door panels and other large, cumbersome parts. Water jet cutting of automotive carpets, rubber mats and car and truck instrument panels, fabricated of vinyl, foam and sheet metal are other typical uses.

Flexible Workcell Concept

Capable of performing an array of tasks, ASI robotic units satisfy the need for flexible automation. A single machine is often programmed to handle a family of parts or assemblies coming down the line. In addition, an ASI system can function as a precision water jet-cutting machine one day, and as a dispenser of adhesives, sealants or other hard-to-handle materials the next.





Dual-station water jet machine with ergonomic tilt tables, dual heads for high-volume instrument panel fabrication.

That's because every ASI machine is essentially a turnkey robotic control system, modular in design so that optional tools, functions or axes of motion can be added as needed. When teamed up with lasers, for instance, versatile ASI robots are capable of performing complex cutting, heat treating, cladding, alloying and a variety of other tasks with unmatched speed and control.

Operator Friendly and Smart... Advantages for the Manufacturer are Many:

ASI machines are delivered totally wired for fast, easy hook-up. And these user-friendly systems require no highly-skilled operator technicians. While ASI systems pack the power of full-capability CNC workcells for technical set-up personnel to manipulate, a simple control console is all that's required by the machine operator.

An ASI robotic system can store up to 99 different programs, all of which can be retrieved manually or automatically through sensors on the line. Motion patterns can be quickly modified using a teach pendant for teach-and-playback programming -- permitting complex engineering changes "on the fly." Machine changeover is reduced to a simple pushbutton operation, with flexibility and productive uptime dramatically increased.

In short, ASI's compact servo-control systems offer the kind of flexible intelligence that greatly simplifies the design, testing and implementation of motion control.

ACCUMOTION

ACCUMOTION

ACCUMOTION

ACCUMOTION

ACCUMOTION

ACCUMOTION

ACCUMOTION

FLEXIBILITY/INTELLIGENCE

MACHINE TYPES

ABRASIVE CUTTING

PICK & PLACE/ASSEMBLY

DISPENSING

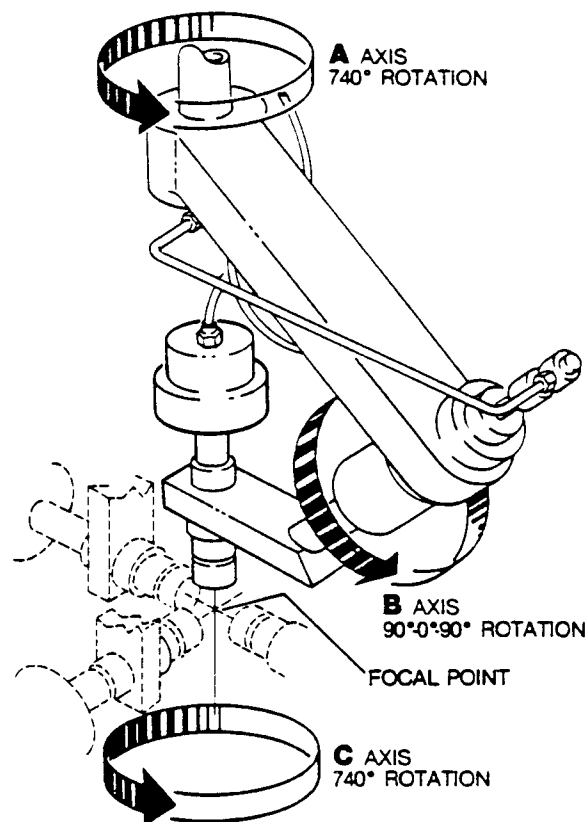
CUTTING

Δ TWIN TACTIC / ET ATOMIC

Motion Control With Split-Axis Drive

ASI systems are standardly equipped with three linear control axes, with up to three additional tilt and/or rotational axes on the tool head optional. The most common configuration is a five-axis setup with 740° rotation on the A-axis and 90°-0°-90° on the B-axis. A sixth axis provides additional rotational capability.

The X, Y, and Z axes are driven by permanent magnet DC servo motors coupled via heavy-duty gear boxes to high-quality, precision rack and pinion drives. The exclusive ASI split-axis drive eliminates mechanical synch bars or driveshafts and has two motors with electronic encoders on each drive for synchronous control. To maximize the benefits from these machines, ASI offers the latest technology in CAD/CAM, CIM and sophisticated pattern nesting.



Major Machine Features

A. Dual-Headed Accu-Cell

1. Tilt Table Design
2. Z-Axis Counter Balance
3. Dual Heads
4. Dual Stations
5. DC-AC Servo Motor Drives

a. Shuttle Table Design

B. Rack and Pinion Drive

1. Anti-Backlash Linear Drive
2. Precision Ways and Racks
3. Z-Axis Brake
4. Linear Interpolator

C. CNC Motion Control Panel with Teach Pendant

D. Gravity Media Filter

E. Vision Systems

F. Heavy-Duty Six-Axis Head

G. Custom Fixture Tables

Additional Design Features:

1. Six-to-Eleven Control Axes
2. Simultaneous Linear Interpolation
3. Repeatability of Part Programming - 0.003"
4. Linear Speed to 3600 IPM Straight Line Travel
5. Electronic Anti-Skewing of X-Axis
6. Optional Laser Alignment Devices
7. Off-Line Programming-CAD/CAM Part Programming
8. Touch Probe/Verification Capability
9. Automatic Tool Changes

Pinpoint Accuracy And Versatility

A reliable family of Allen-Bradley CNC controls are linked to ASI robots to allow operators to select appropriate guidance system programs for any of the numerous operations these versatile machines can perform.

Built-In Safety For Workers

Designed for minimal operator involvement, ASI systems bring a large measure of safety to the shop floor. Machine guards keep operators at a safe distance while machines are running, and scanner panels provide a safety light curtain which automatically shuts down the machine if penetrated.

Return On Investment

The payback period for the ASI robotic systems we've designed, built and installed over the past decade, has been less than one year. In some cases, complete amortization has been achieved in six months or less.

Technical Service - As Near As Your Phone

ASI service personnel stand ready to assist you with field technical support services, 24 hours a day, 365 days a year. Just call: 812-283-7888. Or, in an emergency: 812-282-7630.

Our Commitment to Customer Satisfaction

ASI Robotic Systems today is the leading U.S. manufacturer of turnkey robotic systems and workcells for flexible, integrated manufacturing – systems engineered for modular versatility, reliability and ease of operation. From dedicated, custom-designed production machines to complete, integrated manufacturing systems, ASI is committed to providing industry with the finest machinery, performance and service since 1970.

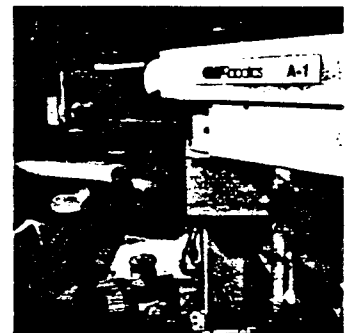
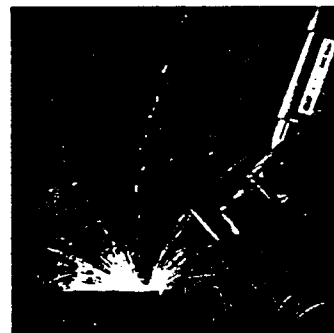
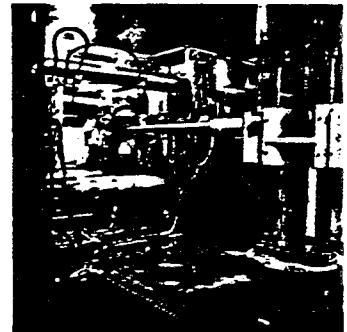
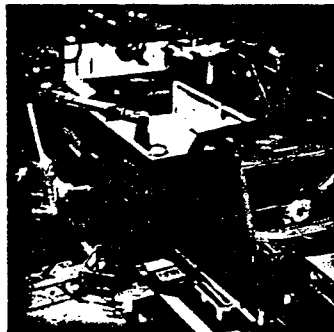
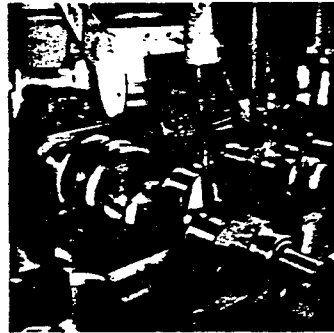
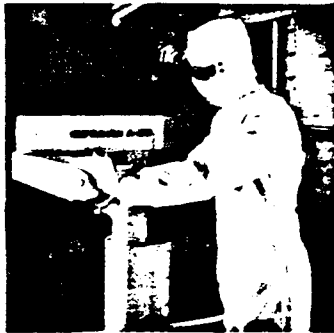


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GMF Robotics

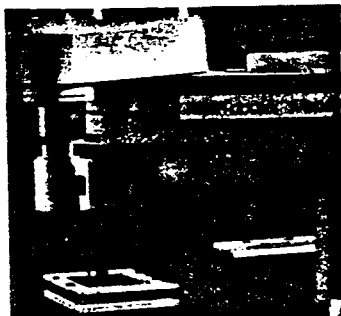
Product Line In Brief



Take Advantage Of GMF Leadership...

- through proven reliability on the factory floor...
- the broadest range of products to meet specific customer needs...
- comprehensive application programs and easy-to-use controllers...
- time-saving workcell design and simulation systems, vision systems, and off-line programming systems...
- and GMF's Total Customer Support.

Standard and Special Purpose Robots For Application Flexibility.



A-600 high speed robot.

A-Series assembly and material handling robots combine application flexibility with the industry's best cost/performance ratio.

The GMF Model A-200 robot is designed for assembly, material handling, inspection, machine load/unload, sealing, and deburring. It provides 3-5 axes of motion.

The GMF Model A-510 is a SCARA-type, AC servo-driven, electric robot. It is designed for high speed, high payload material handling and assembly. The A-510 provides 4-axis, horizontal, articulated motion.

The GMF A-600 is a smaller four-axis SCARA-type robot designed for high speed precision assembly and small part handling.



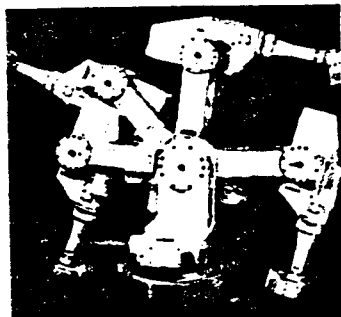
ARC Mate™ welding system.

ARC Mate™ arc welding robots are designed for automating arc welding processes. Two models are available: ARC Mate™ for handling payloads up to 5 kg (11 lbs), and ARC Mate, Sr.™ for payloads to 10 kg (22 lbs).

GMF arc welding robots provide 6-axes of motion and the performance and reliability of digital servo drives, and FANUC AC servo motors with absolute positioning. Repeatability is ± 0.1 mm (± 0.004 " for both models).

S-Series GMF robots handle industrial applications ranging from assembly and material handling to spot welding, adhesive dispensing, and water jet cutting. You can specify payload capacities from 10 to 120 kg (22 to 264 lbs).

S-Series GMF robots are easy to program using GMF's KAREL Controller and programming language.

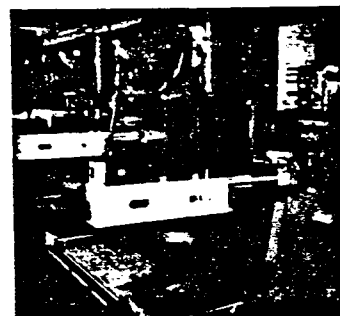


S-700 versatile mid-size robot.

M-Series material handling robots are designed for applications like palletizing, assembly, press loading, die casting, forging, and machine load/unload.

The GMF Model M-100 has the capacity to handle payloads up to 50 kg (110 lbs) in 3-5 axes.

The GMF Model M-300 provides the additional payload capacity to handle workpieces weighing up to 120 kg (264 lbs). This robot also gives you 47" of vertical travel and reach and 3-5 axes under simultaneous control.

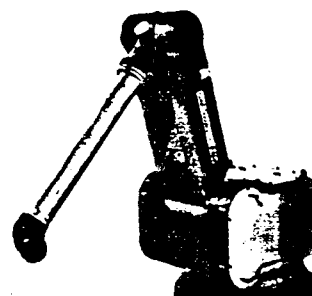


M-100 robots loading presses.

P-Series painting robots are designed to accept standard and special applicators to perform a variety of painting and finishing tasks.

The P-100 is a 6-axis robot designed to operate on a moving line or as a stationary system. It is used for general industrial painting, and to apply automotive paints, underbody deadeners, and anti-chip sealers.

The P-150 painter provides a larger work envelope. Maximum reach travel is 2650 mm (8'8"). It also offers an optional 7th axis to allow for linear travel.



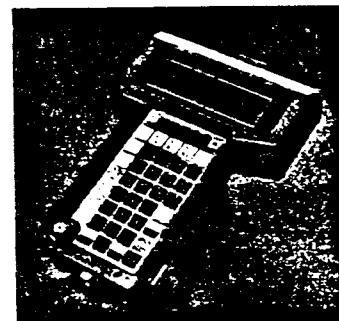
P-150 all electric painting robot.

Basic KAREL® and Enhanced KAREL®

Basic KAREL is designed for quick, simple robot programming and will appeal to initial robot users and shop floor personnel. All programming operations are done on the teach pendant.

Enhanced KAREL offers engineers a powerful, fully structured programming language with such features as:

- Full program branching
- Full arithmetic functions
- Real time I/O monitoring
- User definable messages.



KAREL™ Teach Pendant.

Series		A-Series		
Model		A-200	A-510	A-600
Number of Axes—all simultaneously controlled		3—5	4	4
Robot Motion and Range				
Type		Medium size, assembly	Medium size, high speed assembly, upright or inverted mounting	Small size, high speed assembly
Coordinate System		Cylindrical coordinate type	Horizontal articulated type	Horizontal articulated type
Drive Method		AC servo drive	AC servo drive with absolute position detection	Direct AC servo (2 axes) with absolute position detection
Repeatability*		$\pm 0.05\text{mm}$ ($\pm 0.002''$)	$\pm .05\text{mm}$ ($\pm 0.002''$) $\pm 0.02\text{mm}$ ($\pm 0.001''$) with warm start	$\pm 0.013\text{mm}$ ($\pm 0.0005''$)
Max. Load Capacity		30 kg (66 lbs.) (3 axes) 15 kg (33 lbs.) (4 axes) 9 kg (20 lbs.) (5 axes)	20 kg (44 lbs.)	6 kg (13.2 lbs.)
Application	Arc welding			
	Spot welding			
	Dispensing	○	○	
	Painting			
	Mechanical assembly	●	●	●
	Electrical assembly	○	●	●
	Handling-load/unload	●	●	●
	Handling heavy parts			
	Palletizing	●	●	●
	Material removal			
	Waterjet cutting			

● Primary application ○ Secondary application

ARC Mate

ARC Mate Sr.

S-10

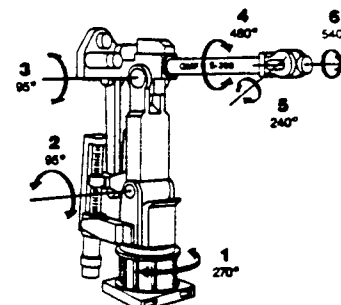
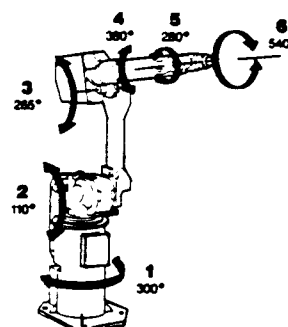
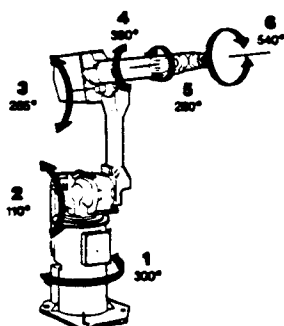
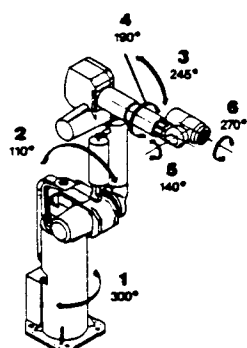
S-200

6

6

6

6



Small size, low cost, high speed
arc welding, upright or inverted
mounting

Medium size, low cost, high speed
arc welding, upright or inverted
mounting

Small size, low cost, high speed

High speed type

Articulated type

Articulated type

Articulated type

Articulated type

AC servo drive with absolute
position detection

AC servo drive with absolute
position detection

AC servo drive with absolute
position detection

AC servo drive with absolute
position detection

$\pm 0.1\text{mm} (\pm 0.004")$

$\pm 0.1\text{mm} (\pm 0.004")$

$\pm 0.2\text{mm} (\pm 0.008")$

$\pm 0.5\text{mm} (\pm 0.020")$

5 lb (11 lbs.)

10 kg (22 lbs.)

10 kg (22 lbs.)

15 kg (33 lbs.)

●

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S-100

S-420

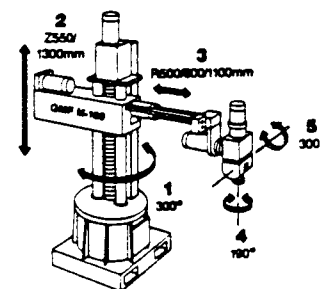
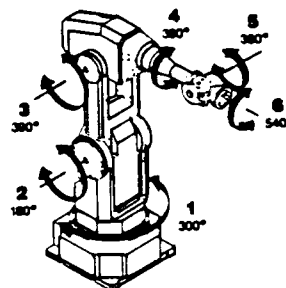
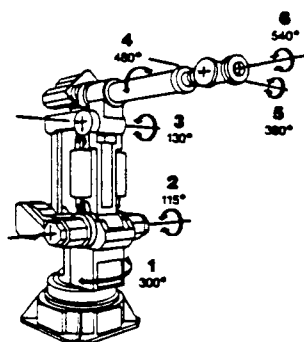
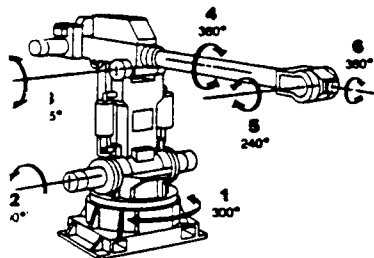
S-700

M-100

6

6

3-5



Large size, upright mounting

Large size, upright or angle mounting

Medium size, low cost, upright or inverted mounting

Versatile material handling

Articulated type

Articulated type

Articulated type

Cylindrical coordinate type

AC servo drive with absolute position detection

AC servo drive with absolute position detection

AC servo drive with absolute position detection

AC servo drive

 $\pm 0.1\text{mm} (\pm 0.020")$ $\pm 0.5\text{mm} (\pm 0.020")$ $\pm 0.2\text{mm} (\pm 0.008")$ $\pm 0.5\text{mm} (\pm 0.020")$

100 kg (220 lbs.)

120 kg (264 lbs.)

30 kg (66 lbs.)

High speed type
(with options available)
50 kg (110 lbs.) (3 axes)
35 kg (77 lbs.) (4 axes)
31 kg (68 lbs.) (4 axes)
20 kg (44 lbs.) (5 axes)

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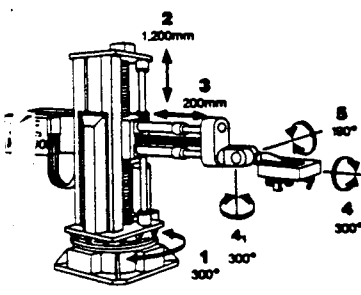
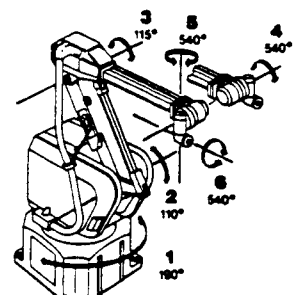
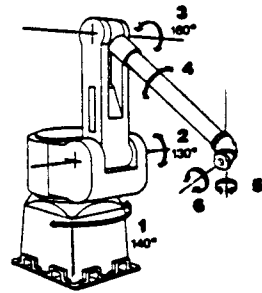
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○

P-Series		Series	
300	P-100	P-150	Model
	6	6—7	Number of Axes—all simultaneously controlled
 <p>Note: 4, (4th axis with E-series)</p>		 <p>Axis 4,5,6 = summation of 1080°</p>	Robot Motion and Range
Material handling heavy workpiece	All-electric, intrinsically safe paint finishing, with lead-through teach	All-electric, intrinsically safe paint finishing	Type
Cylindrical coordinate type	Articulated type	Articulated type	Coordinate System
AC servo drive	AC servo drive with absolute position detection	AC servo drive with absolute position detection	Drive Method
mm	± 0.5mm (± 0.020")	± 0.5mm (± 0.020")	Repeatability*
20 kg (264 lbs.) (3 axes) 100 kg (220 lbs.) (4 axes) 130 kg (176 lbs.) (4 or 5 axes)	5.0 kg (11 lbs.) at 60mm offset	4.5 kg (10 lbs.) at 200mm offset	Max. Load Capacity
			Arc welding
			Spot welding
	○		Dispensing
	●	●	Painting
○			Mechanical assembly
			Electrical assembly
●			Handling-load/unload
●			Handling heavy parts
●			Palletizing
			Material removal
			Waterjet cutting

Application

*Repeatability by same direction and same speed approach.

Controls, Software, Vision and Programming Aids To Increase Productivity.

Powerful, Easy Programming Controls/Software.

The GMF KAREL Controller is a complete control system including hardware, programming language, and operating system. It provides full program/edit capabilities, self-diagnostics, and user-friendly support of GMF standard and special purpose robots.

The KAREL system delivers performance proved in more than 10,000 installations. It is also the most reliable robot controller on the market. Measured mean time between failures is 40 months of two shift operation, over three years of factory floor use.

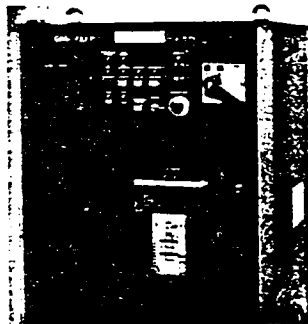
KAREL hardware and operation software are designed to make programming tasks easy and fast to perform. Advanced technology digital servos provide faster, and smoother robot motion and path performance over slower analog systems.

Standard controllers can support over 1 MB of RAM for program and point execution, and over 3 MB of bubble mass storage for programs and point data.

The powerful KAREL robot programming language gives you menu-driven operator functions, "MAP" communications, remote operator panel or CRT operation, optional portable keyboard/CRT, and a hand-held teach pendant.

Personal Computer- Based Off-Line Programming.

GMF's Personal Computer-Based Off-Line Programming system (OLPC) provides a low cost method of developing KAREL application programs for GMF robots. Because you program off-line, you do not tie up your robot controller



KAREL® Control System.



PC-Based Programming System

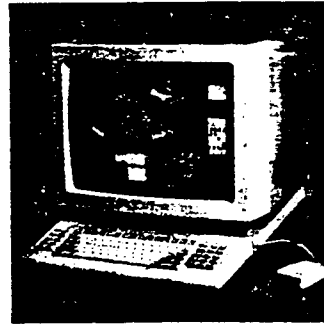
and interrupt production. Programming errors are also minimized because you're working in an office environment, not on the shop floor.

With GMF's OLPC system, you can write applications programs on IBM industrial computers, IBM-PC XT/AT's and PS/2 computers, as well on selected 100% IBM-PC compatible computers.

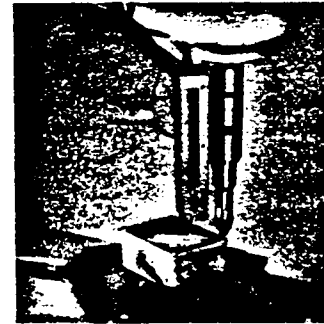
To accommodate your particular programming requirements, GMF gives you full capabilities of off line programming of KAREL applications. OLPC allows you to upload and download programs to a KAREL Controller, edit the programs you create, plus convert your programs into KAREL executable format to conserve memory capacity in your KAREL controller.

Off-line Robot Program- ming Workstation.

GMF's OLPW-200 package is a graphics and simulation



OLPW-200 Programming Workstation.



GMF INSIGHT™ Vision System

system (similar to a CAD workstation) that holds images of each GMF robot and kinematics to run each robot. This allows you to create complete robot programs and simulate workcell design and robot paths on a CRT. This cuts installation time and eliminates false starts and tool crashes.

With the OLPW-200 system, you can create, modify, and view 3-D objects like robots, fixtures and workpieces, and position these elements within your workcell. Next, you add end-of-arm effectors, then use a mouse and menu interface to create your robot program. It is now possible to simulate all motions on a screen to check for collisions and robot position programs. Your edited and optimized program is then downloaded to your KAREL Controller.

The OLPW-200 system speeds the design and layout

of workcells. It also eliminates most of the startup problems associated with creating new workcell environments. This is particularly beneficial in low-to-mid volume manufacturing applications where equipment has to frequently be converted to handle changing production requirements.

GMF INSIGHT™ Integral Vision System.

GMF's Integral Vision System gives GMF A-Series, M-Series, S-Series the ability to "see." Our gray scale vision capabilities can support automatic calibration requirements, 2-D and 3-D fixturing, measurement and inspection programs, and workpiece positioning and sorting needs.

The INSIGHT System provides the best price/performance ratio of any vision system on the market. This is achieved by sharing packaging of a GMF KAREL controller. The integral vision system itself consists only of 3 PC boards which plug into the robot controller.

The integral vision system can be programmed to use up to 8 cameras using a portable teach pendant or off-line programming system. Its true grayscale processing capability of 256 levels allows the system to be used in applications with low contrast lighting and variations in part appearance without the use of special lighting.

Applications for the INSIGHT System range from locating parts for proper orientation on machines, determining fixture offset, and verifying part position in assembly applications, to inspecting for the presence of a weld bead or sealer bead.

State-of-the-Art Technology Plus Total Customer Support.

Training To Meet Your Specific Needs.

GMF's philosophy of Total Customer Support begins with professional instruction of your personnel. We understand that the tasks of operating, programming and maintaining your robotic system require differing skills and information and have carefully designed our award winning training and documentation to match these needs.

Proof of our commitment and experience are the more than 20,000 sq. ft. we have dedicated to customer training, 25 robots dedicated to hands-on orientation, and over 10,000 people already trained.

Additionally, recognizing you may have special needs, GMF is experienced in developing training and documentation programs to meet individual customer requirements.

Parts Planning For Maximum Uptime.

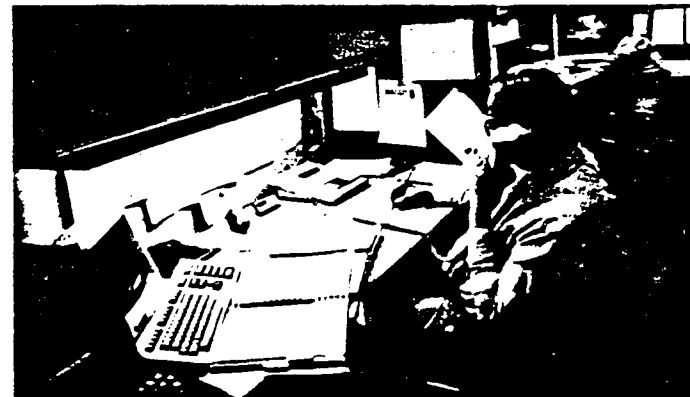
GMF Support includes tailored spare parts programs, designed to meet your specific needs and ensure maximum system uptime. GMF works with you to define the type and quantity of parts



Training



Parts



Hotline

you will maintain on site, plus provides an ongoing assessment of your changing needs based on your in-house maintenance requirements and historical performance.

In addition GMF can ship parts on an immediate basis from our multi-national inventory stocks in the United States, Canada and Europe. We stock more than 15,000 different part numbers valued at over \$30 million.

Around The Clock Service Support.

GMF service personnel are available 24 hours a day via our Service Hot Line. More than 300 customers a month take advantage of this program, saving thousands of hours of downtime a year.

GMF experience and depth (more than 500 man-years of product service and more than 50,000 man-hours per year in the installation of robotic systems) are the reasons why our service is consistently rated by our customers better than 8 on a scale of 10.

Finally, we offer flexible contracts to put a GMF service expert in your plant on a continuing basis, to meet your specific needs and in-house capabilities.

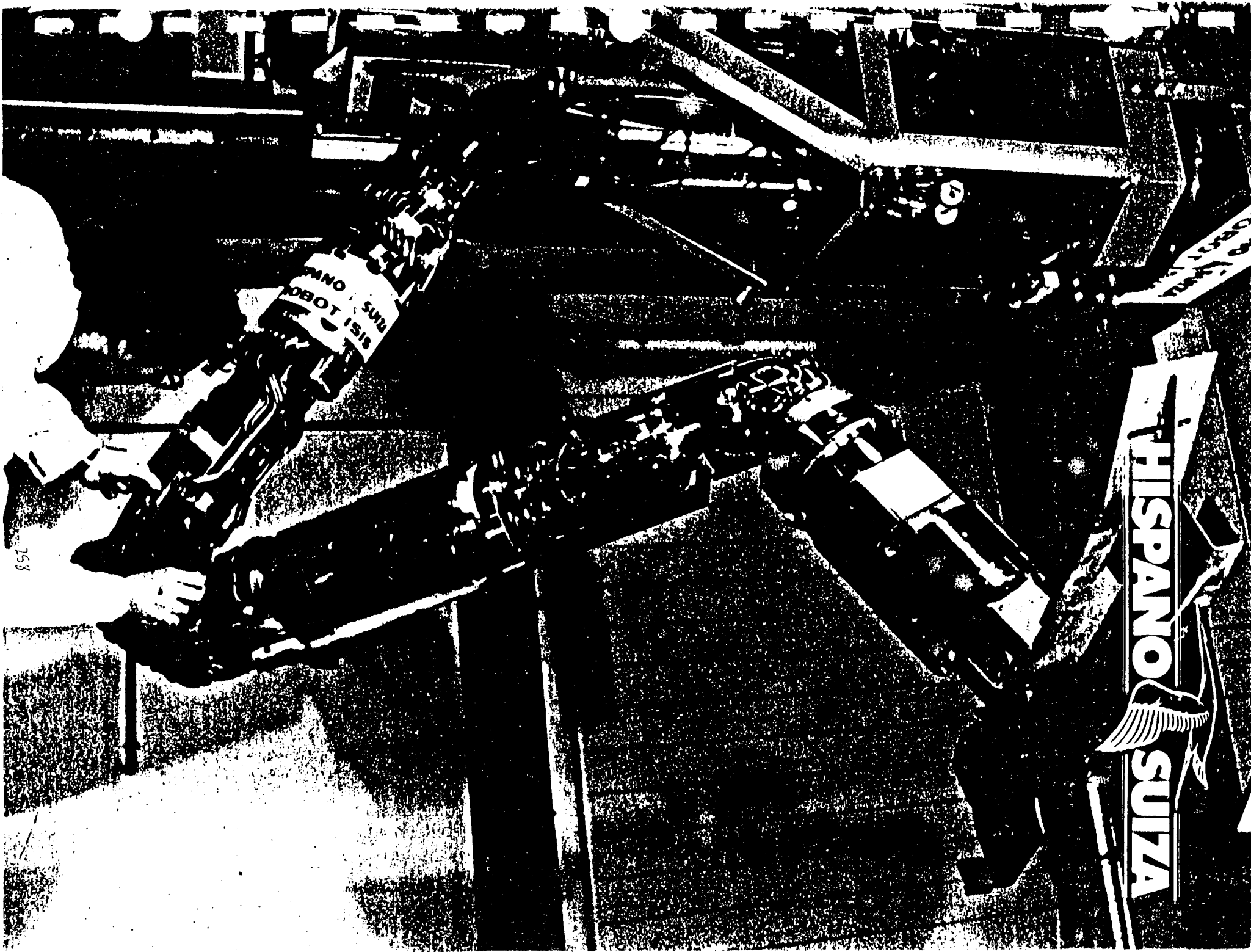
GMF Robotics

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Main Office (313) 377-7000

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Main Office 011-49-211-250040

Specifications subject to change without notice
AP-6/R 10M 2-89 F&R LITHO IN U.S.A.



HISPANO SUIZA
ROBOT 1518



ROBOTIC and NUCLEAR DIVISION

BP 60 - 92270 BOIS-COLOMBES FRANCE .

TELEX : 620 131 HISPA F - TEL : (33) (1) 760 50 22
(33) (1) 760 51 66
(33) (1) 760 51 20

GENERAL

1. SUMMARY

HISPANO-SUIZA can provide a full range of inspection and maintenance tools for your nuclear and fuel reprocessing plant equipment.

2. ROBOTIC AND NUCLEAR ENGINEERING

Qualified and experienced mechanical, electrical, computer engineers and technicians make up our engineering and maintenance service teams.

Since 1956, HISPANO-SUIZA has designed and manufactured a large range of specific nuclear equipments such as :

- The handling and refuelling systems for the first nuclear plant E.D.F. 1
- Control rod mechanisms for B.W.R.
- Refuelling mechanisms for fast breeder RAPSODIE and PHENIX

Presently, HISPANO-SUIZA is developping and producing :

- Automatic radwaste-barrels handling mechanisms for the reprocessing plant COGEMA - LA HAGUE
- The fuel cladding grinder and solid transfer unit for the MARCOULE's COGEMA MAR 400 plant
- The ISIS Robots for inspection and maintenance of the CHINON A 3 nuclear plant.



ROBOTIC and NUCLEAR DIVISION

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(1) 760 51 66
(1) 760 51 20

- Displacement Speed

Maximum : 15 sec. for flexion
30 sec. for rotation

Adjustable from 0 speed to max.

5. Operation control computer unit

Multi processor structure 16 bits at 8 MHZ and 5 MHZ

Memory capacity :

640 K BYTES RAM or ROM

WINCHESTER OF 35 MEGA BYTES

- . Sampling frequency of electro-hydraulic control : 100 Hz
- . Sampling frequency of control acquisition and strain return : 10 Hz.

A robot computer unit comprises :

- 1 central control unit (able to control 3 robots)
- 1 local computer unit and electronics
- 1 power electronical supply
- 1 hydraulic unit
- 1 electric generator for welding operations
- 1 robot.



ROBOTIC and NUCLEAR DIVISION

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(33) (1) 760 51 20

B - END-OF-ARM TOOLING-HEADS AND ACCESSORIES

HEADS

- Telemetric head
- Scouring head - pecking process
- Scouring head - grinding process
- Electric welding head
- Handling head
- Universal clamp

ACCESSORIES

- Part holder
- Head holder

For further information, please contact :

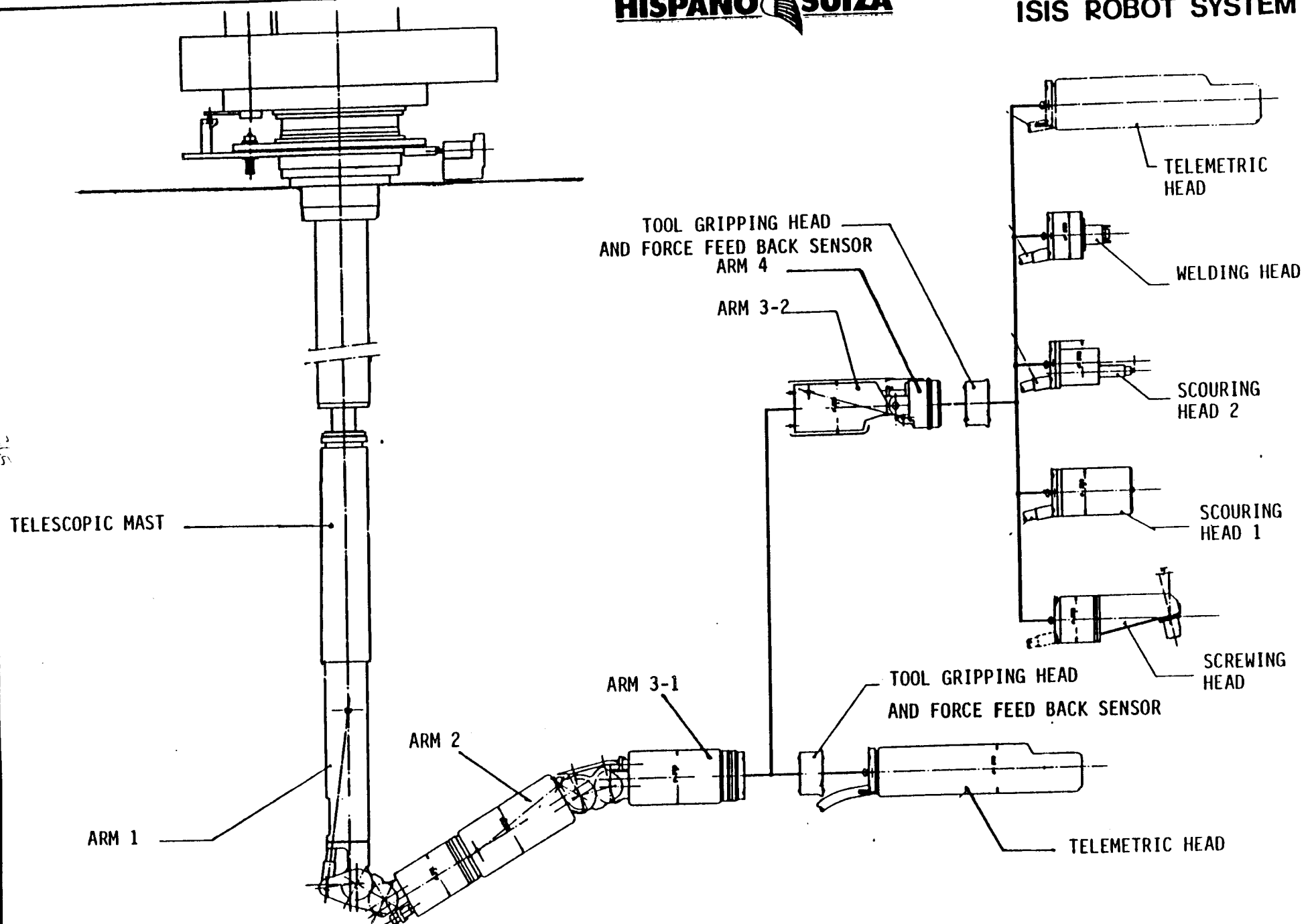
HISPANO-SUIZA
ROBOTIC and NUCLEAR DIVISION

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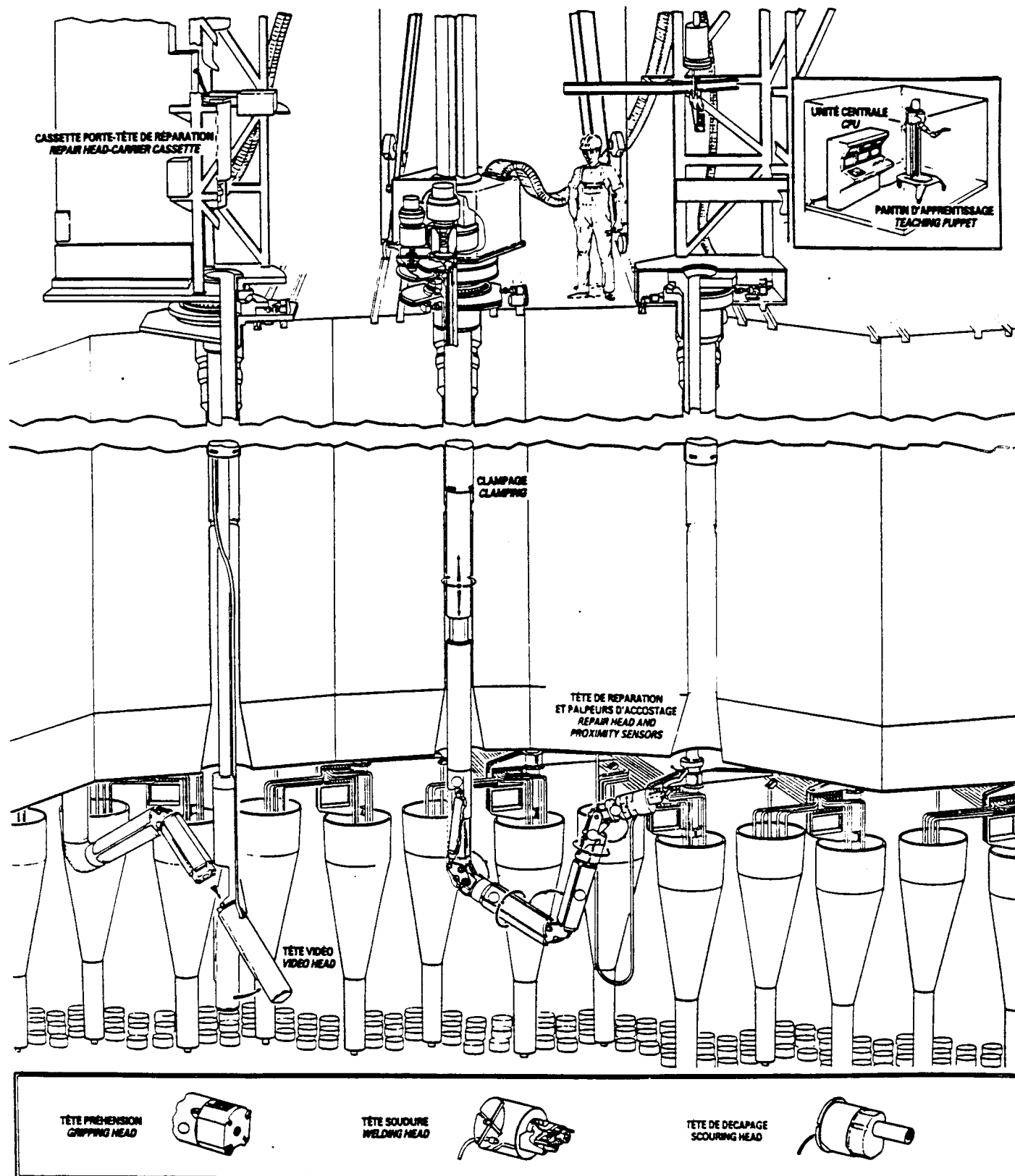
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ENSEMBLE D'INTERVENTION ROBOTISE EN MILIEU HOSTILE ROBOT FOR OPERATIONS IN A HOSTILE ENVIRONMENT



HISPANO-SUIZA DIVISION ROBOTIQUE & NUCLEAIRE

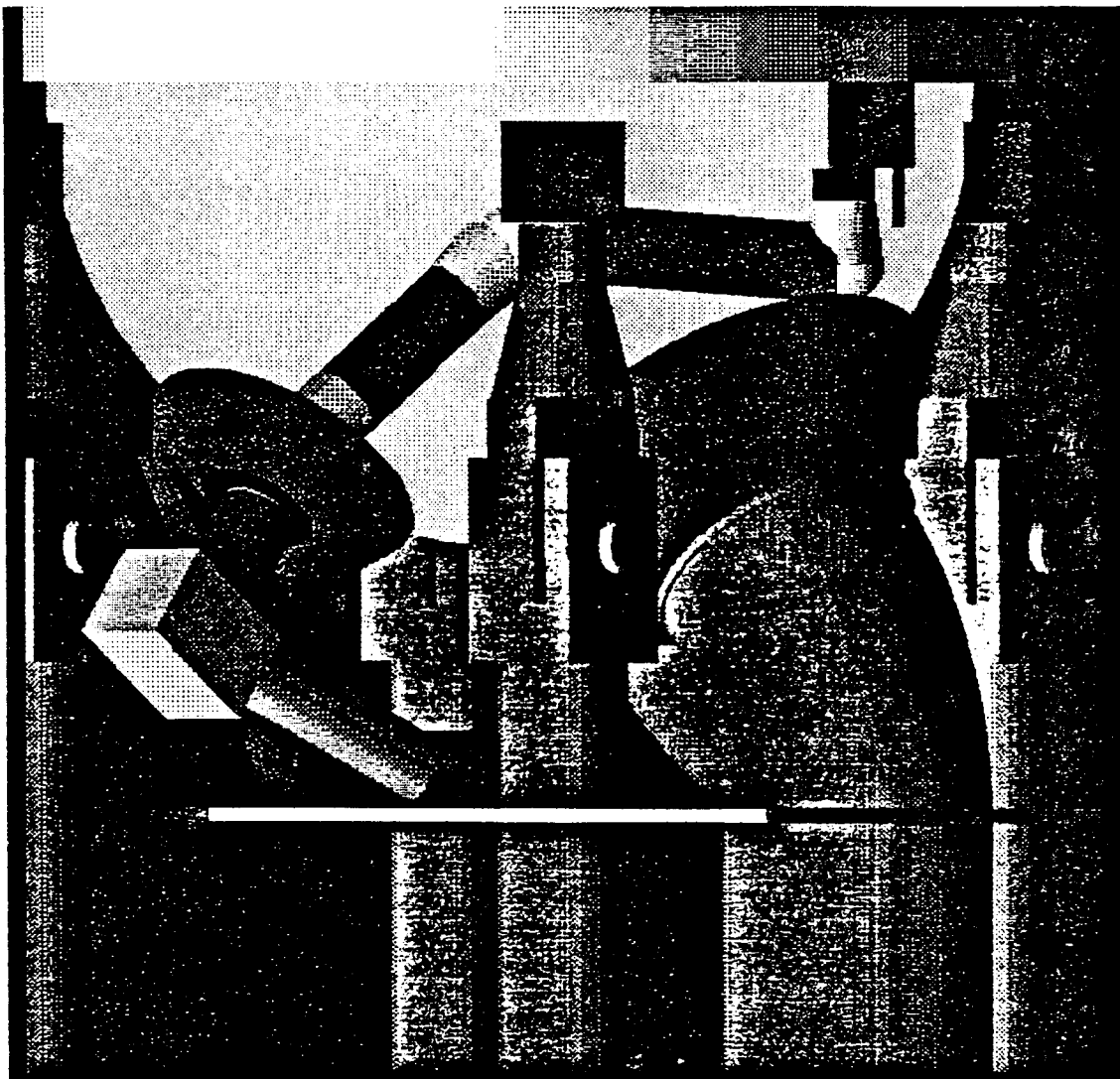
B.P. 60 - 92270 BOIS-COLOMBES FRANCE

TÉL. SERVICE COMMERCIAL (1) 760.50.22 et 51.66 SERVICE TECHNIQUE (1) 760.51.20



ISIS[®] | ROBOTS

THE MAINTENANCE BREAKTHROUGH FOR HOSTILE ENVIRONMENTS



Electricité de France



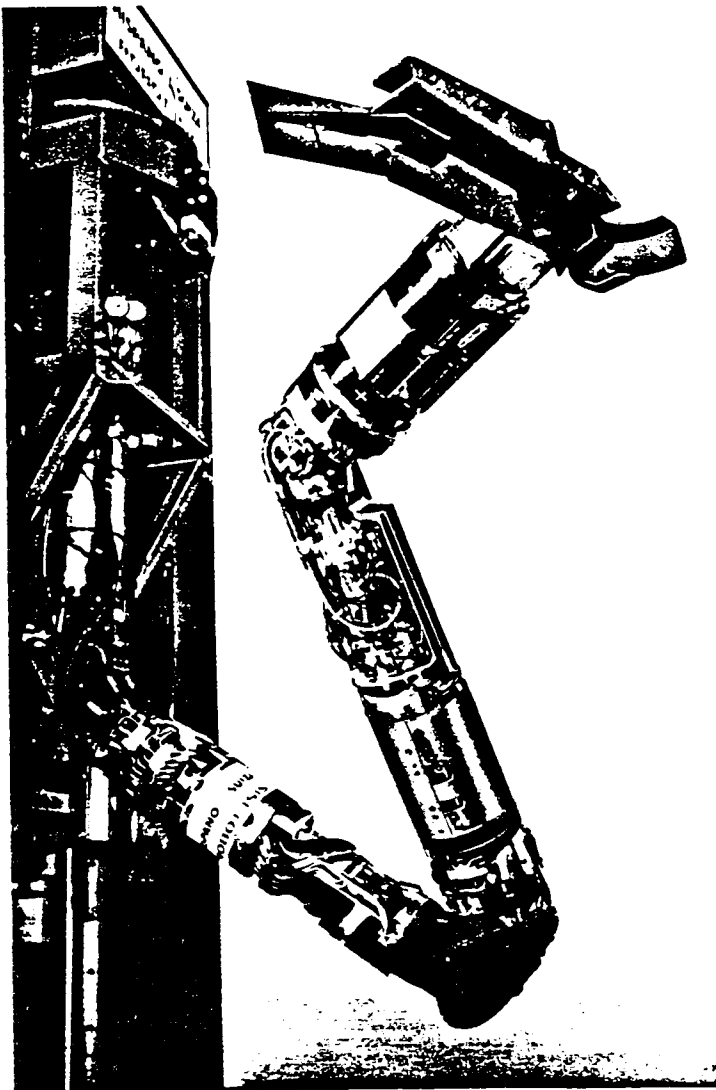
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ISIS 1 ROBOT

GGC REACTOR MAINTENANCE ROBOT

ACHIEVING THE IMPOSSIBLE

The ISIS 1 ROBOT is the remarkable achievement of an intensive engineering effort by EDF and HISPANO-SUIZA to develop equipment for remote-handling of reconditioning the upper structures of the Chinon A3 GGC reactor. These structures were badly corroded by hot carbon dioxide but it was impossible to repair them by direct human intervention. The ISIS 1 ROBOT, operating in a 70 °C atmosphere and heavy radiation conditions, successfully coped with the various repair tasks and the Chinon A3 reactor has been back in service since December 1987.



FEATURES:

- Telescopic mast: 7.5 m length
- Jointed arm: 2.5 m length
- Load capacity: 70-110 kg
- Arm diameter: 0.22 m
- Positioning accuracy: 0.2 mm
- Equipped with a 3-D force and torque sensor
- 8 degrees of freedom
- Sensitive skin to detect obstacles

APPLICATIONS:

- Telemetric inspection
- Structure scouring
- Preparation for welding
- Repair parts welding
- Stud welds testing
- Installing/removing screws
- CAD pre-calculated routes

ACHIEVEMENTS:

- More than 400 studs in core welding
- Five robots in operation
- Operation in excess of 35,000 cumulative hours
- Successful repairs on the Chinon station (back in service since December 1987)

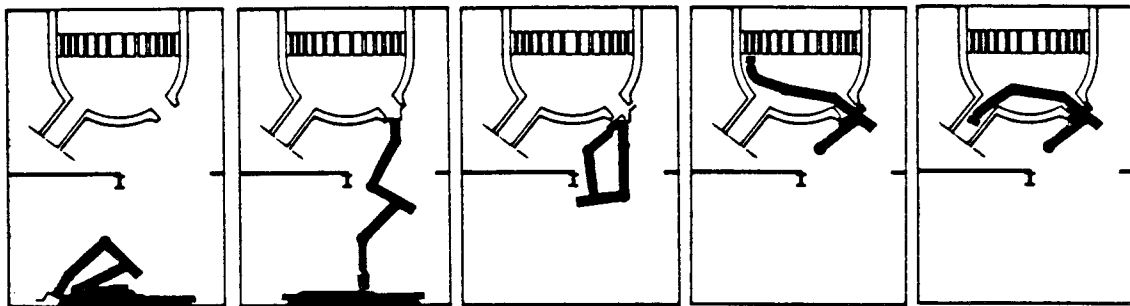


ISIS 2 ROBOT

MULTI-TASK PWR STEAM GENERATOR MAINTENANCE ROBOT

A NEW GENERATION OF VERSATILITY

Lighter, more versatile and harder working, the ISIS 2 ROBOT (now in development) takes the significant achievements of the ISIS 1 ROBOT one step further in meeting a wide variety of maintenance challenges in PWR power plants. With an impressive freedom of movement and a positioning precision of 0.2 mm, the ISIS 2 is capable of handling a hefty 150 kg using a choice of tools on its universal adaptor. The automatic unfolding and positioning capability vastly reduces the radiation exposure to personnel.



FEATURES:

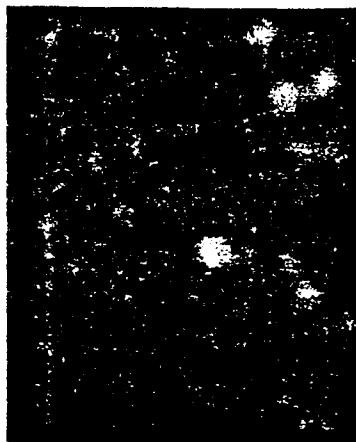
- Weight: 250 kg
- Arm length: 2.5 m
- Arm diameter: 0.22 m
- Load capacity: 100-150 kg
- Positioning accuracy: 0.2 mm at the end of arm
- 8 degrees of freedom
- Disposable skin

ADVANTAGES:

- It's a polyvalent robot
- It's heavy duty robot
- It's self-positioning
- Easily decontaminated, it can be used in many sites
- Reduced exposure to personnel

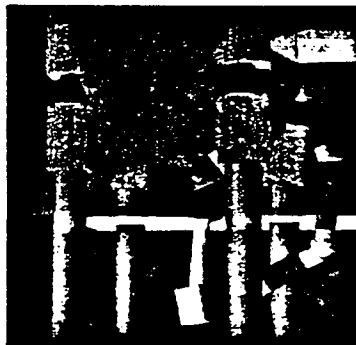
NEW POSSIBLE APPLICATIONS:

- Electro-decontamination of channel head
- Repair of channel head without the need to fix itself on the tube sheet
- Inspection of welds
- Primary input and output inspection, decontamination, and welding

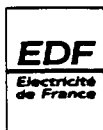


A SUCCESSFUL PARTNERSHIP IN PROBLEM SOLVING

After successfully achieving the remarkable engineering feat of ISIS 1 ROBOT in key maintenance challenges of Chinon A3, EDF was encouraged to go forward with HISPANO—SUIZA in developing a second generation robot, ISIS 2, for operation in PWR plants. The ISIS 2 ROBOT is scheduled for use at the end of 1988.



CONTACTS:

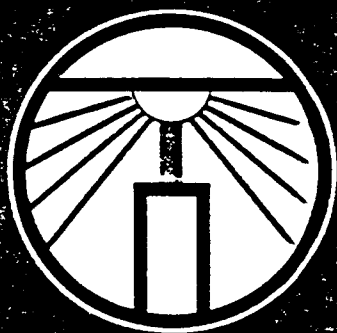


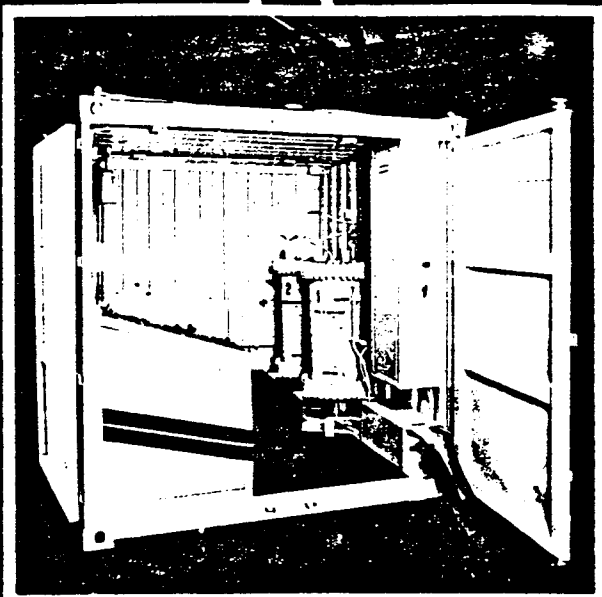
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Immeuble "Le Central 2"
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Hydro-Cut Systems





The Hydro-Cut System is an advanced hydro-mechanical development which uses pressurized water and abrasive particles to cut and clean steel, alloys and a wide range of other resistant materials. It is based on a technical development by The British Hydro Mechanics Association which has over 20 years experience in research and development in the field of high-performance hydromechanics.

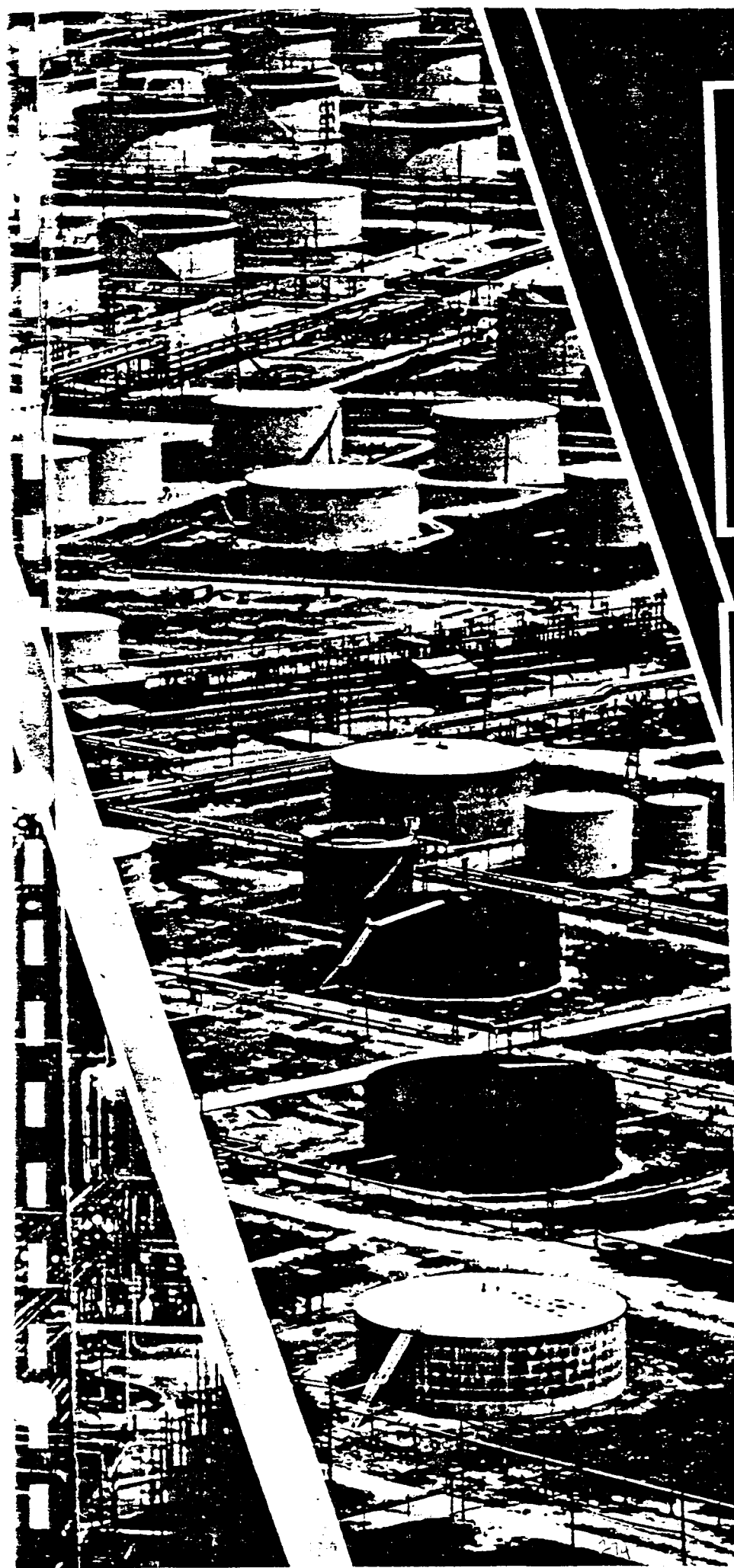
Hydro-Cut Systems were amongst the first US companies to realize fully the industrial potential of the hydro-abrasive principle, as a safe and cost effective alternative to conventional oxy-acetylene cutting methods.

Hydro-Cut Systems provides on site custom cutting services. The wide range of industries which take advantage of Hydro-Cut's advanced and economical performance demonstrate the versatility of the system; applications range from nuclear power generation to civil engineering, subsea installations to petrochemicals.

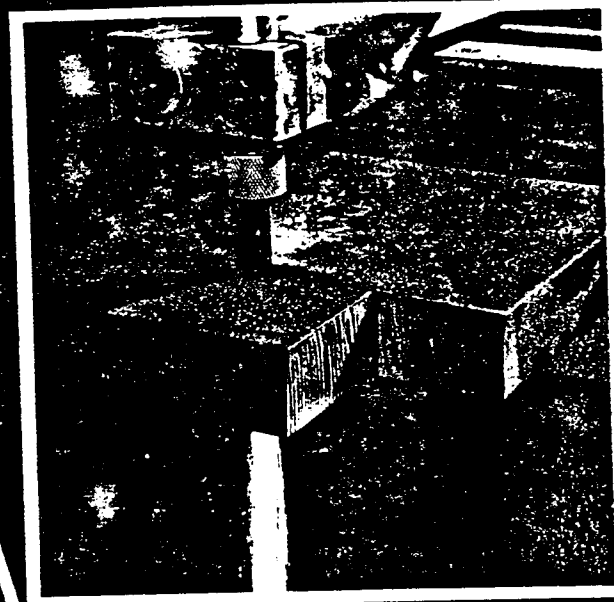
The Hydro-Cut System requires abrasive and a water supply to be fully operational and is highly effective over a very wide spectrum of high grade steels, alloys and refractory materials. Operating at a maximum pressure of only 4,000 psi, the most difficult refractory can be cut in a single operation. By comparison, the same result using oxy-acetylene equipment can only be achieved by lengthy, and costly, multiple processes. In addition, the system is designed to be very versatile and maneuverable in use with tracking equipment which enables the operator to cut a pipe or plate instantaneously to a pre-set weld angle and standard.

A major advantage of Hydro-Cut over oxy-acetylene cutting is that it operates without generating heat or vibration. Whereas oxy-acetylene cutting incurs inherent drawbacks such as stress to and distortion of the material and the build up of slag and burrs. The abrasive particles used in the Hydro-Cut System create a clean finish requiring minimal welding preparation without risk of weakening the surrounding material.

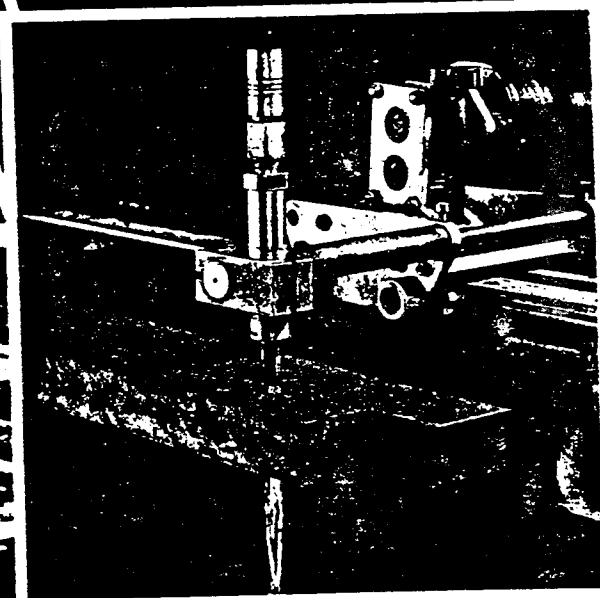




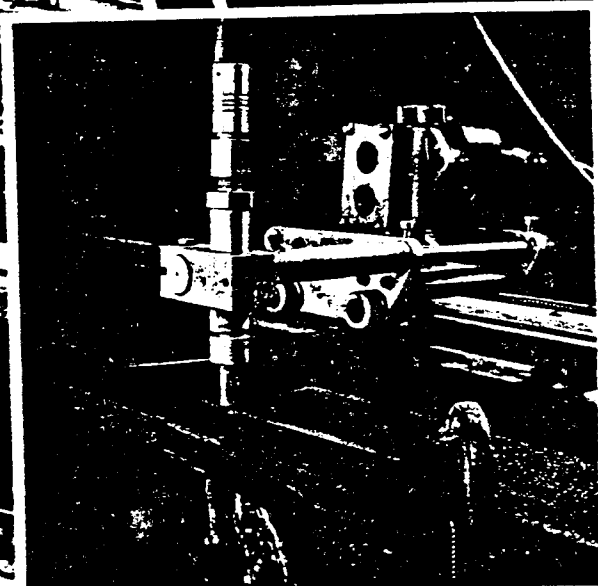
Linear tracking. Cutting 2" armour plating



Cutting rigid PVC section



Cutting 1 1/2" rubber section
Shaw hardness 2C





Cutting 2" high carbon steel well-pipe.
with 10° weld-prep.

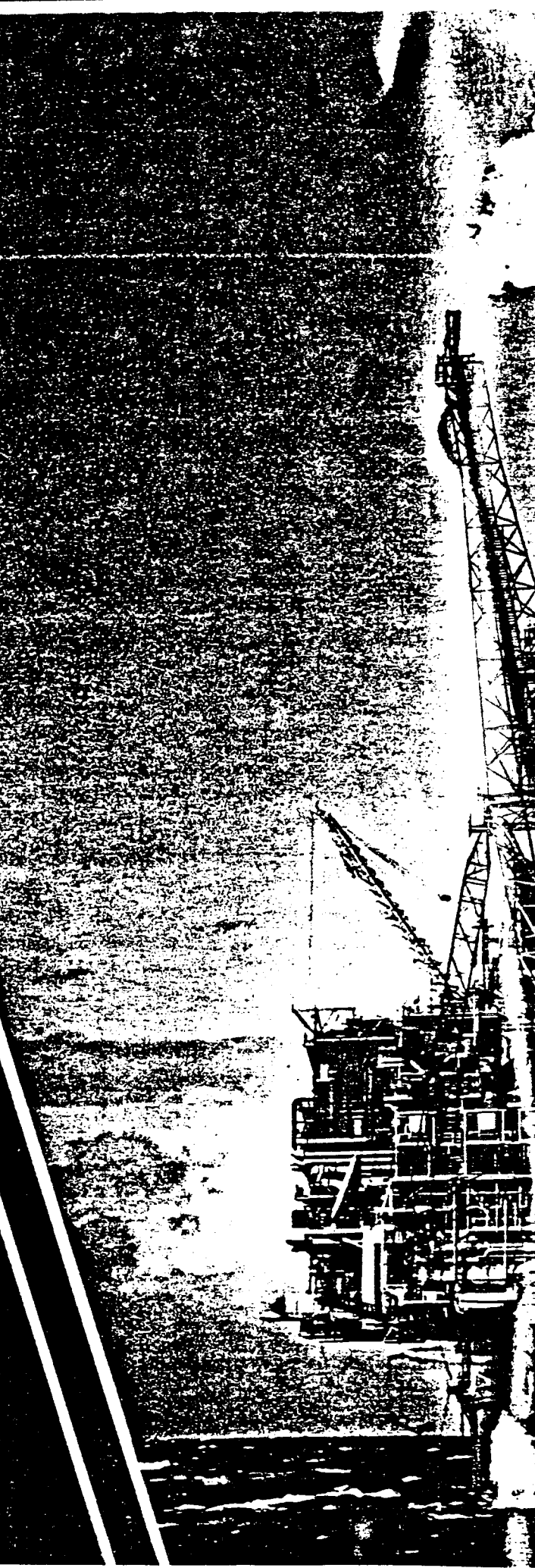
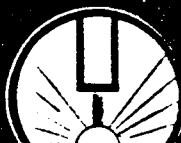
The Hydro-Cut System is designed and constructed to high standards of safety and reliability, complying with legislation governing both onshore and offshore cutting equipment.

The system requires only abrasive and a water supply to operate. Its compact modular design allows operations in confined areas with optimum versatility.

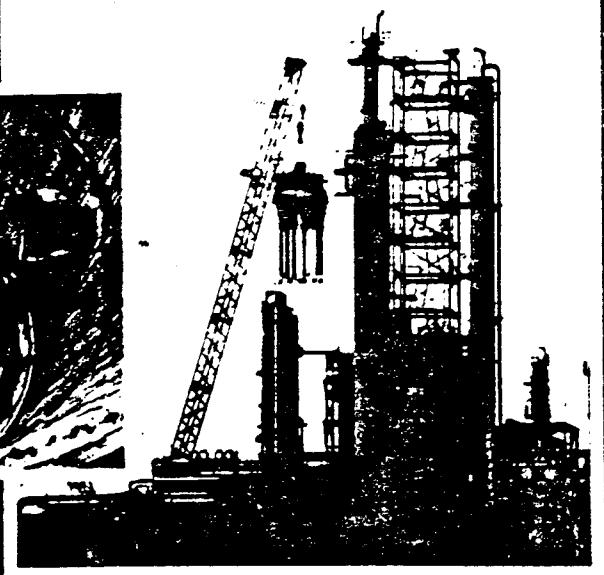
The Hydro-Cut System is ideal for general maintenance operation, requiring minimum shut down time compared to alternative cleaning and cutting systems. It also enables materials to be cut to precise depths within one millimetre of totally severing the material. The apparatus can therefore be used with complete safety where underlying materials must remain intact. The precision cutting required for such operations cannot be guaranteed by any other cutting method.

The Hydro-Cut System features a single hydraulic control unit to control both the reverse and forward tracking speeds. This allows the system to be exceptionally maneuverable for offshore and tank farm applications where it is not always possible to have the machine in close proximity to the cutting area. Cutting operation can be performed effectively and accurately at distances of up to 1,500 feet away from the power source by linking the control unit in at any line connection and providing the necessary visibility for accurate control of the cutting operation. This advanced control feature allows Hydro-Cut Systems to tackle effectively tasks for which oxy-acetylene cutters would be rendered useless.

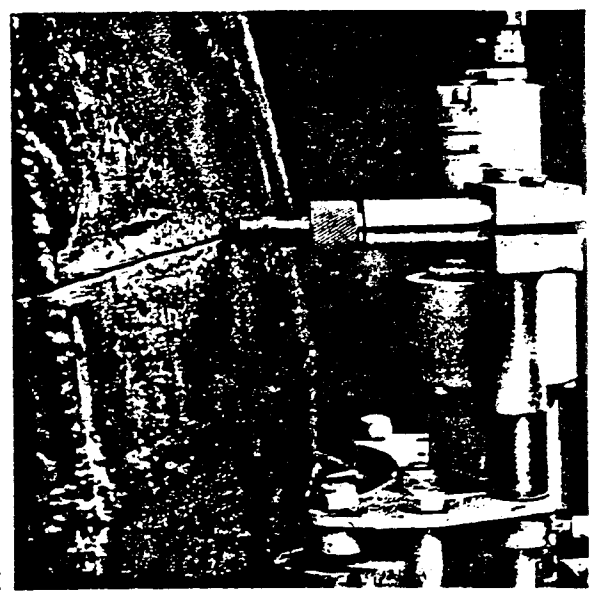
Extensive works have been undertaken for the following major petro-chemical companies:
British Petroleum, Shell, Esso, Texaco;
Mobil, I.C.I., Conoco, Chevron.



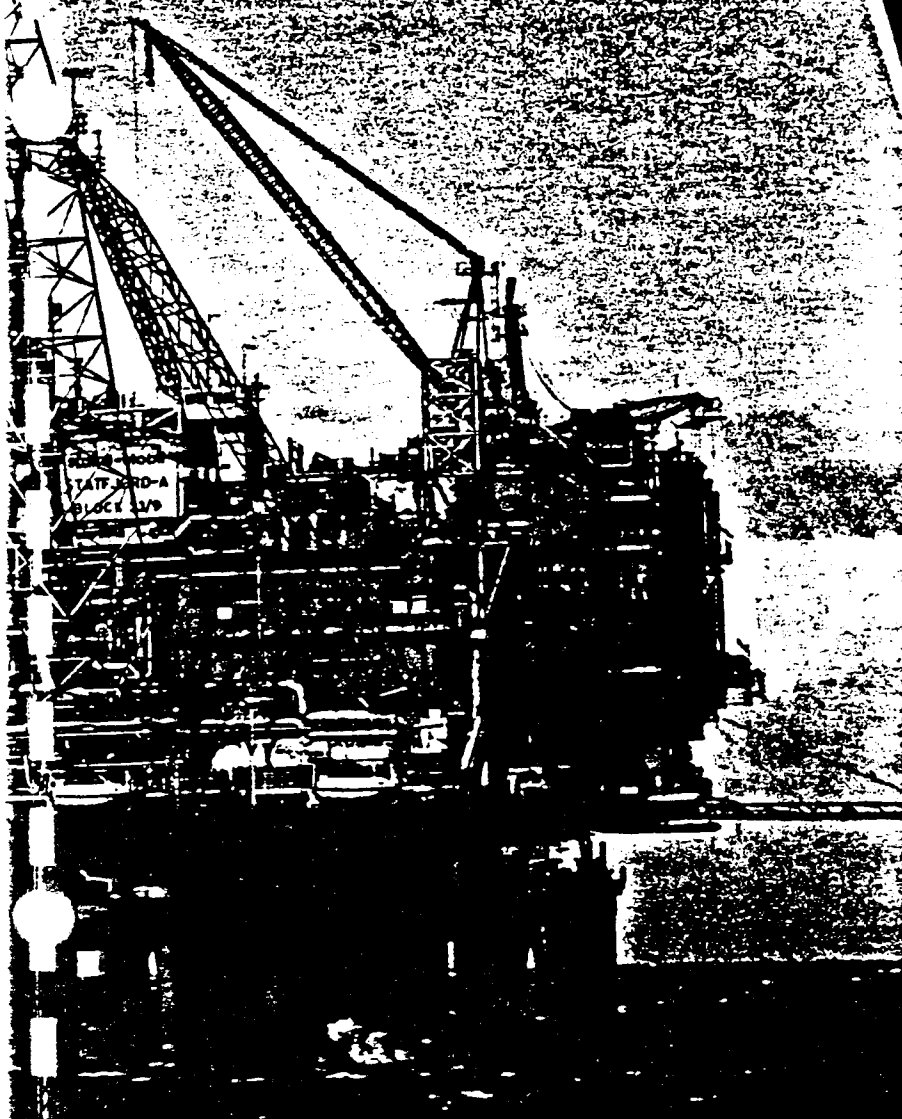
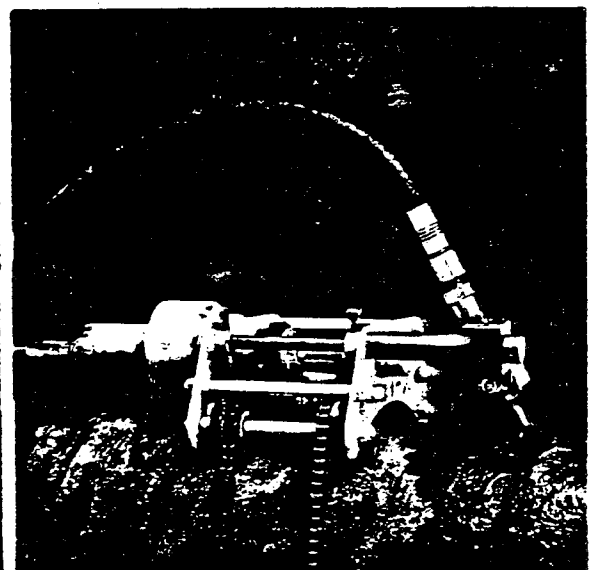
Removal of head from regenerator involving a composite cut of $\frac{1}{2}$ " carbon steel, 4" of refractory, including hex-mesh reinforcing

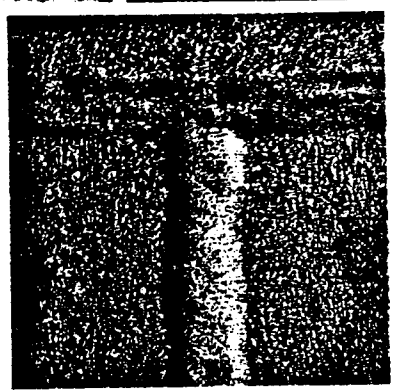
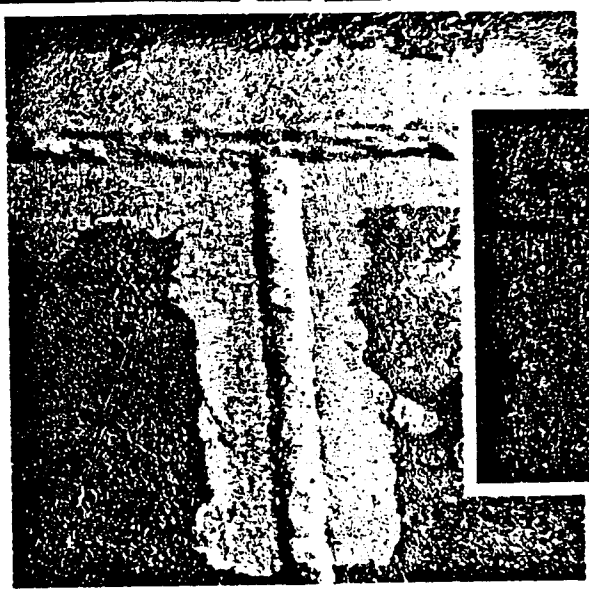


Circumferential tracking of a distillation column



Typical cut through reinforced bitumen lined $\frac{3}{4}$ " carbon steel pipe line





Critical weld preparation prior to N D T of subsea structures

BLASTING FACILITY

Hydro-Cut also has available a Tungsten Carbide Blasting Nozzle, which when replacing the Cutting Nozzle converts the apparatus to a powerful blast cleaning tool

Hydro-Cut effectively reduces the time, equipment and expense of blast cleaning by transporting the abrasive to the blasting head as a ready mixed slurry, which requires only one $\frac{1}{2}$ " BSP transportation hose. Other hydro-mechanical abrasive systems require dry abrasive to be injected into the cutting head, a procedure which demands complex and costly rigging apparatus

The system is recommended for use over a wide range of surface contaminants, including catalytic carbon deposition, LSA scale and marine crustacea. Surface coatings such as epoxy polyurethane, fiber glass and rubber can also be quickly and safely cleaned away using the blasting nozzle

At greatly reduced pressure Hydro-Cut performs as a highly cost effective alternative to conventional shot-blasting equipment for the cleaning of stone, brickwork and concrete structures

SUBSEA APPLICATIONS

The Hydro-Cut System has been developed to give cutting and blast cleaning results under subsea conditions, similar to cutting, weld preparation and blast cleaning standards as on surface operations

The system is an effective means of removing marine growth, bitumen and corrosion from subsea structures. It is therefore a particularly valuable subsea inspection tool, blast cleaning areas not easily accessible to conventional cleaning apparatus such as hydraulic brushes. Areas vulnerable to subsea degeneration, such as weld caps and heat affected structure weld zones can be quickly and thoroughly cleaned and inspected without necessitating lengthy and expensive D S V and dive times, which can involve cumbersome rigging procedures



BENEFITS

- Safety

The Hydro-Cut System has the ability to cut into volatile or hazardous containers or other hazardous environments eliminating time consuming and costly preparation routines.

- Reliability

The Hydro-Cut System has an excellent record of reliability and is on call 24 hours per day, 7 days per week.

- Cost Effectiveness

The system can accommodate most abrasive material enabling the cheapest source to be used. Copper Slag is the ideal medium, but sand, garnet, aluminium silicate, olivine and fused alumina are all effective materials.

- Simplicity

The minimum of rigging is required, making the system light and maneuverable.

- No Depth Limitations

The system is entirely hydraulic, avoiding the use of pneumatic or venturi effects, which could hinder deeper subsea operations.

- Adaptability

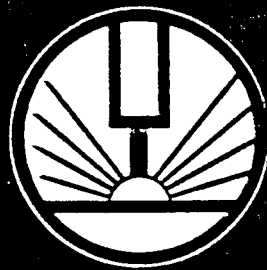
The Hydro-Cut System performs well under diver, tracking manipulator or R.O.V. control, and can thus be employed in hazardous conditions without risk to personnel.

Hydro-Cut System in blasting mode - removal of thick film reinforced bituminous coating.



Removal of catalytic carbon deposition from internals of reactor/regens.





Hydro-Cut Systems

FOR FURTHER INFORMATION OR QUOTE DETAILS CONTACT
HYDRO-CUT SYSTEMS AT 1-800-343-7211

P.O. Box 5591, 3005 South Treadaway, Abilene, Texas 79608.
Telephone: 915-691-0430, Facsimile: 915-692-0898



Hydro-Cut Systems

PRICE SCHEDULE
2-1-90

Each cut is unique and will be bid on an individual basis.

1.0 Mobilization

- 1.1 Mileage: \$2.50 per mile F.O.B. Houston
- 1.2 Per diem: \$75.00 per man per day (3-man crew)
- 1.3 Cancellation: \$1,000.00 charge if job is cancelled after crew has departed.

2.0 Rigging and Cutting

- 2.1 Hourly Rate \$ 350.00 per hour
- 2.3 Precision Hourly Rate..... \$ 500.00 per hour

3.0 Stand By

- 3.1 Stand by rate: \$200.00 per hour; based on 10 hour work day "Gate to Gate".
- 3.2 Minimum daily charge:\$1400.00 (4 hours cut rate)

All invoices are due and payable 15 days following the invoice date. All invoices are due and payable in Abilene, Taylor County, Texas.

PRICES SUBJECT TO CHANGE WITHOUT NOTICE



A Subsidiary of Possis Corporation

Ultra-High Pressure Waterjet Cutting and Cleaning Equipment

Tom Luckemeyer
Account Executive

Jet Edge, Inc.
825 Rhode Island Ave. So.
Minneapolis, MN 55426

612-545-1477
800-JET-EDGE
FAX 612-545-5670

What is

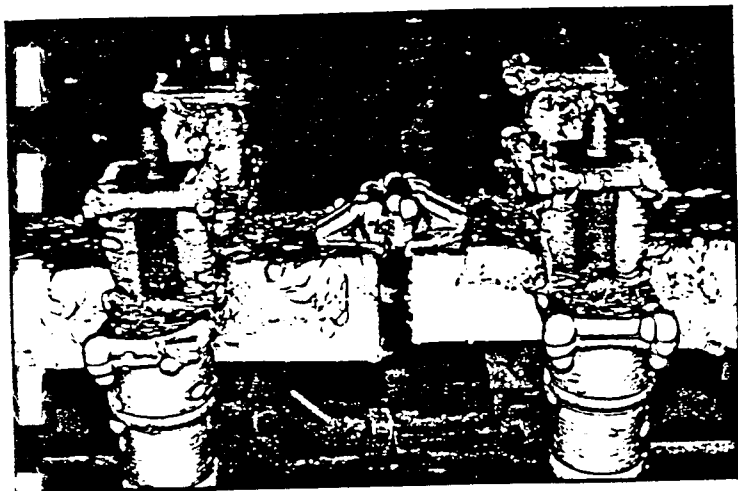
Jet Edge® doing
A Subsidiary of Possis Corporation

with

36,000+ psi

ultra-high water pressure...?

Everything!



Waterjetting... solves your toughest cutting and cleaning problems.

How does waterjetting work? With an ultra-high pressure waterjet stream, the Jet Edge system provides a cutting or cleaning tool that can never wear out. The system concentrates enormous power that penetrates virtually any material.

The powerful Jet Edge water stream is delivered through flexible hoses to the operator-held lance, or directed with the aid of a

programmable automated motion control device. The low-volume use of pure, on-site water means clean, economical production. Proper nozzle and tool selection assures superior production rates with no damage to surrounding material.

Jet Edge tackles the toughest cutting, cleaning or surface preparation job in your plant or factory. Cuts through concrete for

• coatings removal/surf • industrial cleaning

removal on buildings, roads and bridges. Penetrates multi-layered coatings build-

up of paints and plastics. Even hard steel and alloys are cut cleanly! Jet Edge

Multiple Applications... with Jet Edge

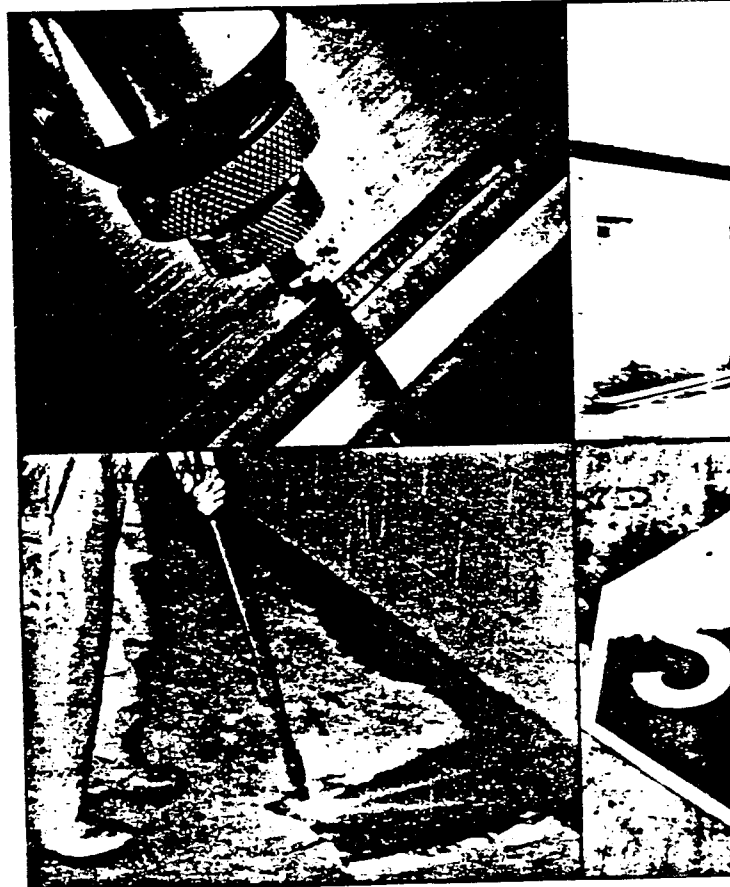
Coatings removal and surface preparation

Does your equipment suffer from build-up of coatings, elastomers, epoxy, corrosion, scale or other surface deposits? Ultra-high pressure waterjetting cuts through these problems in a hurry — right down to the substrate. No film or chemical residuals. No solvent fumes. No degradation of the substrate or hardening of materials. Apply a new coating to a surface perfectly prepared with Jet Edge technology and assure maximum

coating adhesion to that surface. Induce a profile or accelerate removal rates by adding an abrasive to the ultra-high velocity waterjet.

Industrial cleaning

Deposits and residues are completely washed away by the jet stream. No chemicals are needed. Jet Edge users include plants and factories, mills, utilities and power plants, refineries, marine facilities and others. Waterjetting cleans overhead and vertical surfaces, spray booths, emission



ice preparation

reduces costs, time and manpower to deliver the production you demand.

versatility.

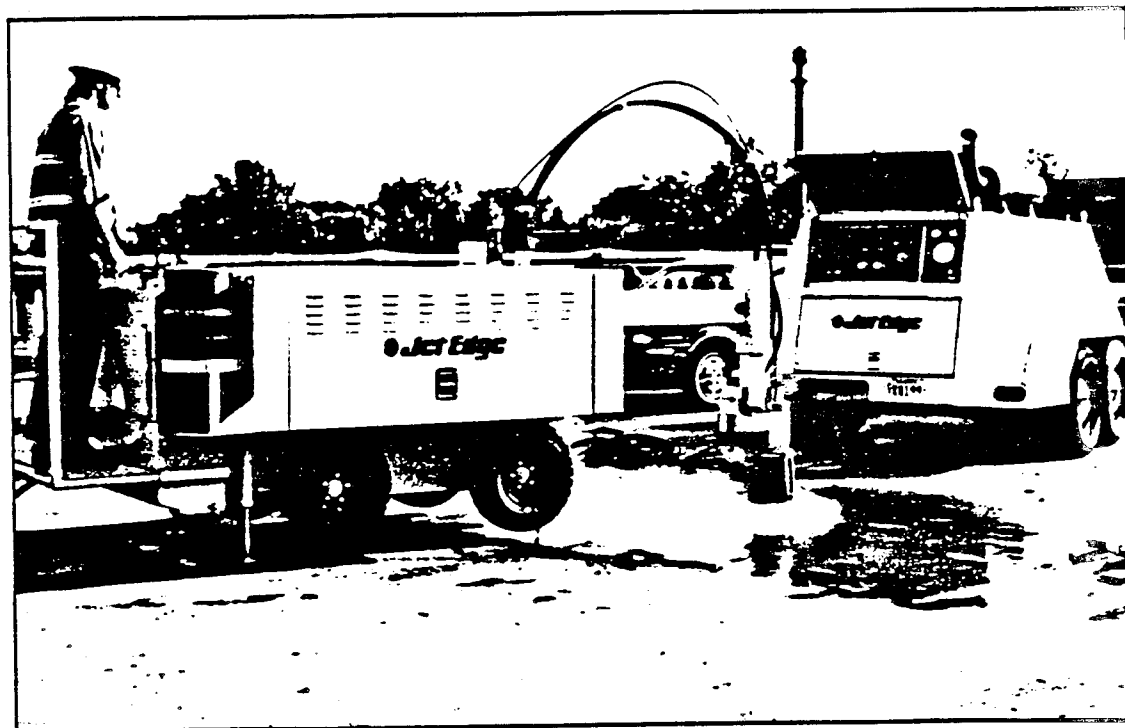
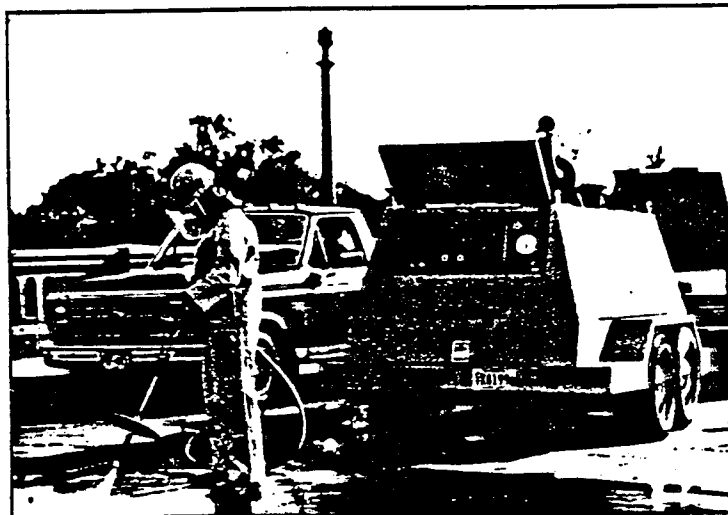
cuts, gratings, tubes and piping. No surface is too large or too obscure to escape Jet Edge coverage and penetration.

Controlled hydrodemolition where impact tools cause damage to structurally-sound materials, waterjetting cuts cleanly. Removes only the material you want removed. Concrete is disintegrated with no damage to re-inforcing steel. And you don't break the steel's bond with good concrete away from the cutting point.



- portable abrasive jet cutting
- controlled hydrodemolition

Cracked or spalled concrete is eliminated with less operator fatigue than heavy impact tools. And there's no airborne dust! Solid cores of thick concrete are precisely cut for removal, leaving a rough bonding surface for reconstruction. Debris and road salts are washed away. Hydrodemolition with Jet Edge... it's cleaner, faster, safer.



Portable waterjetting/cutting
The self-contained, portable Jet Edge system can be truck-towed to any site. The one-operator system may be used as far as 500 feet from the power unit for multi-use cutting and

cleaning. Indoors, for plant or factory application, or outdoors on highways or structures, the Jet Edge low profile and light weight allow quick set-up in confined areas. Cut without sparks: re-inforced concrete, plate

steel — virtually any material without inducing heat affected zones. Any shape can be cut including curves.

Jet Edge
A Subsidiary of Possis Corporation

Waterjetting. Consider what you don't get.

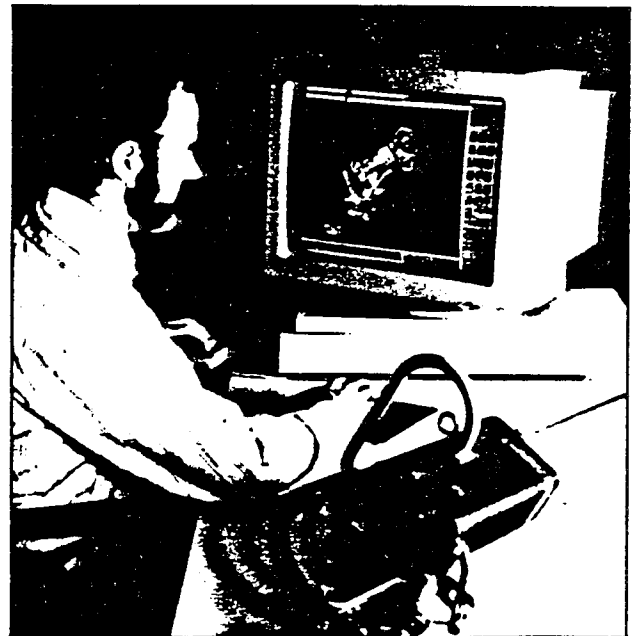
- ***no sharpening or replacement of mechanical cutting tools.***
- ***no heat generation to cause spark ignition or metal fatigue.***
- ***no hazardous (explosive or toxic) airborne particles.***
- ***no ventilation facilities or solvent recovery systems needed.***
- ***no damage from impact vibrations.***
- ***no costly containment or disposal problems.***

Jet Edge Design and Engineering... for uncomplicated reliability.

JAD/CAM designed with the latest ultra-high pressure waterjet technology, the Jet Edge power unit provides optimum service and low maintenance. The heart of the system is the powerful intensifier-type pump with a double-acting piston that creates pressures up to 60,000 psi. The result is the water stream velocity that can exceed Mach 3. The stream is delivered through a low cost, replaceable

sapphire orifice at the tip of the operator's lance, providing exact directional control.

Simplicity of design and components is the key to Jet Edge hydrotechnology. No exotic parts to replace. Just basic, precision-engineered components that meet the highest standards of quality. Standards that meet or exceed your performance expectations.



Jet Edge

A Subsidiary of Possis Corporation

825 Rhode Island Avenue South • Minneapolis, MN 55426
612-545-1477 • 800-JET-EDGE • FAX 612-545-5670

The Jet Edge Gyra Jet is engineered to operate with all Jet Edge mobile power units as well as any high pressure pumping system. This hand held portable tool uses ultra-high pressure water at up to 36,000 psi for coating removal and surface preparation. The high speed rotary head action gives you excellent productivity while maintaining consistent controlled finish requirements.

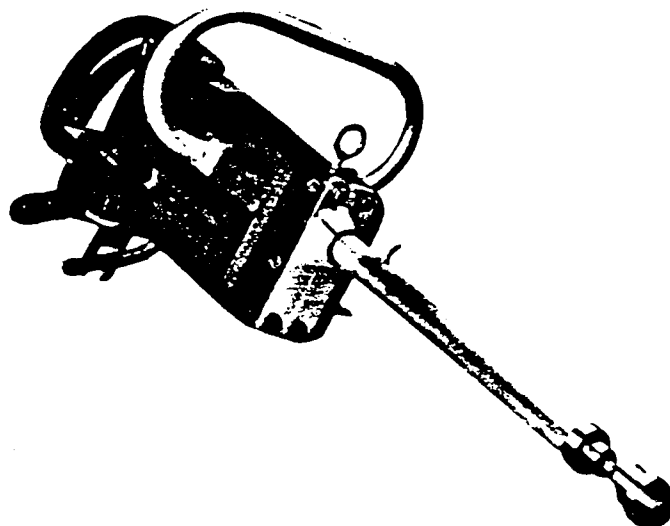
The Gyra Jet receives ultra-high pressure water and low pressure hydraulic pressure through flexible lines. Hydraulic pressure is utilized to rotate the head and actuate the Gyra Jet high pressure water valve. Water on/off actuation force is extremely low, thus reducing operator fatigue. Rotational speed is infinitely adjustable at the Gyra Jet with the built-in hydraulic flow control for speeds up to 1500 rpm.

Select from a wide variety of standard end effector manifolds to satisfy your requirements. Manifolds for tube cleaning, coating removal, surface preparation and scarification are among the choices.

Compact design permits use in tight quarters while retaining complete control with comfortable hand grips. The trigger detent promotes operator safety.

This tool is precision machined from the highest quality materials for extended service in hostile environments. Hydraulic fittings are of the dry break positive locking style.

When productivity and efficiency are demanded the Gyra Jet is the best tool for the job.



Specifications:

Hydraulic Oil Pressure	1500 psi max
Rotation Speed	1500 rpm max
Water Pressure	36,000 psi working

Physical Size:

Length	22.5 in.
Width	4.5 in.
Height	6.0 in.

Manifolds Available:

- 2 orificed for cleaning greater than 3/4" I.D. Tube
- 4 orificed for cleaning greater than 2" I.D. Tube
- 4 orificed for surface cleaning

Contact Jet Edge for the availability of other manifold configurations.



Model L300 UltraLite Lance

Specifications

Current rated
Operating Pressure up to 36,000 psi

Physical Size

Length 9 in.
Height 8 in.
Standard Weight 7 lb.
(Including Extension)

Options:

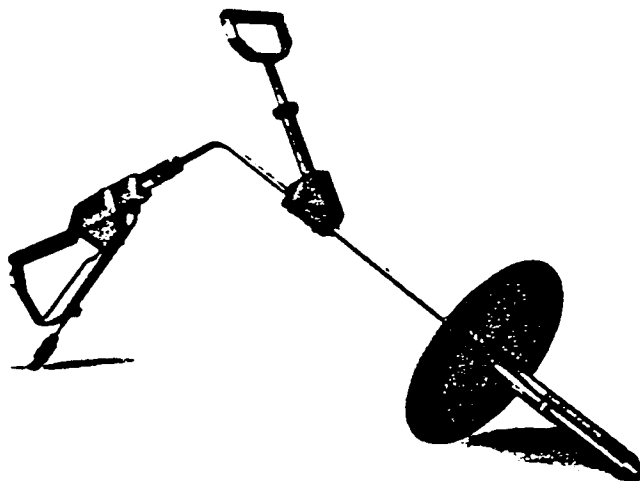
Attenuator Style Tip
Fixed Orientation Fan Tip
Rotatable Fan Tip
Custom extension tube lengths and
configurations available upon
request (Autoclave 9/16 in. H.P.)

Fan Tips

.014
.018
.026

Orifices:

Up to .050 with our standard retainer



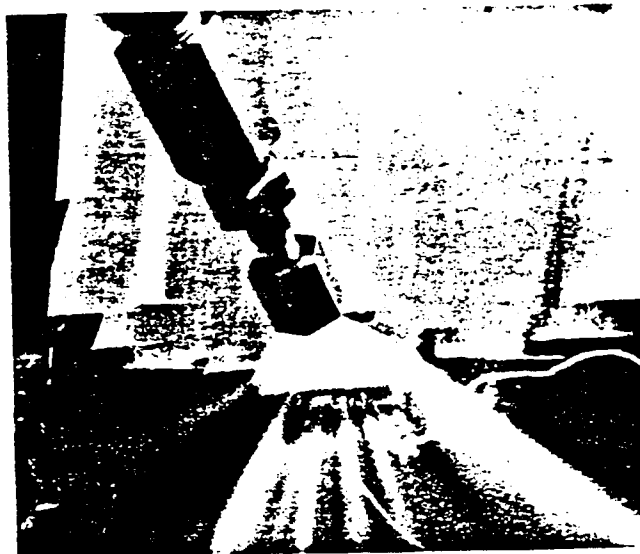
Model L110 JetLance II

Specifications

Current rated
Operating Pressure up to 36,000 psi

Physical Size

Length 16 in.
Height 6 1/2 in.
Standard Weight 14 lb.
(Including Extension)



Fan Tip

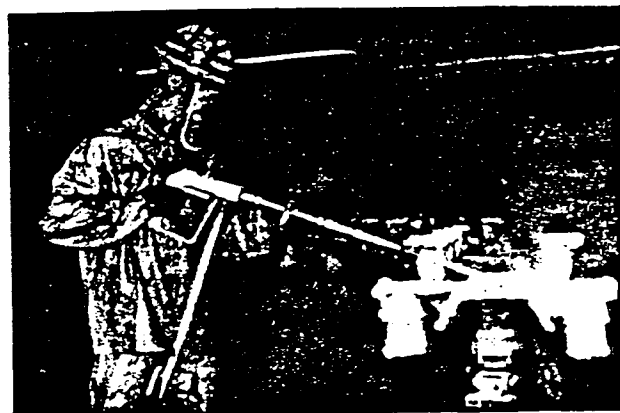
UltraLite Lance

The Jet Edge Model L300 UltraLite Lance and L110 JetLance II may be used in conjunction with any Mobile Power Unit or pump. These portable, hand held tools utilize ultra-high pressure water of up to 36,000 psi for waterjet cutting and cleaning applications. The light weight design, low actuation force, and extremely low reaction force greatly reduce operator fatigue. Typical applications include coating removal, surface preparation, industrial cleaning, and controlled surface demolition.

The UltraLite Lances are easily attached to standard ultra-high pressure hose with durable stainless steel fittings. Engineered for safe operation, all hose and fittings are placed conveniently away from the operator. Generous contoured grips and trigger provide hours of comfortable operation. Long life heavy duty poppet style construction for instant ON/OFF action. Integrated trigger guard prevents unintentional actuation on all models. A body weight of only 5 pounds for either the UltraLite or Jet Lance makes these tools popular with operators.

Functionally identical, only the body style varies between the ULTRALITE LANCE and JETLANCE. The UltraLite Lance is easily held in a natural horizontal position to alleviate operator fatigue when used for vertical or overhead applications. The design of the Jet Lance aids in effortless positioning on horizontal surfaces.

A variety of extension tube lengths and configurations available. Extension tubes and handles are interchangeable between the two models. Choose between the standard orifice or fan tip assemblies, and the wide variety of orifice and fan tip sizes offered.



Fan Tip

The Jet Edge Fan Tip (patented), used with either the UltraLite Lance or JetLance, is the only wide pattern jet available rated to 36,000 psi. Available in three sizes, the Fan Tip provides a simple and cost effective solution to many difficult cleaning problems. These include scarification, decontamination, coating removal, cleaning of underwater structures, film removal, and concrete laitance removal. Surfaces are completely cleaned of all chemicals and soluble salts, providing a high quality bondable surface for new coating applications. Hazardous airborne dust contamination and waste disposal problems are eliminated. Rotational adjustment of the Fan Tip coupling allows 360° control of the fan angle for precise positioning of the jet stream. Designed for extremely long life while operating at 36,000 psi, the Jet Edge fan tip is unsurpassed for coating removal and surface preparation.

Attenuator Tip

Utilizing the proven benefits of laminar flow, the Jet Edge Attenuator Tip concentrates the power of ultra-high pressure water through a man-made sapphire in interchangeable retainers. This coherent stream can cut through concrete, asphalt, PRC, or rock along with most organic materials.

Choices

Jet Edge offers a complete range of portable ultra-high pressure pumps from **40 hp to 250 hp**. This family of units assures you the optimum pressure and flow rate for your application. These units utilize hydraulic power to drive plunger style intensifiers. The use of hydraulic fluid provides the **smooth flow** of the ultra-high pressure water resulting in **long life** of the system. Highly refined control systems give you the ultimate in system versatility.

Control

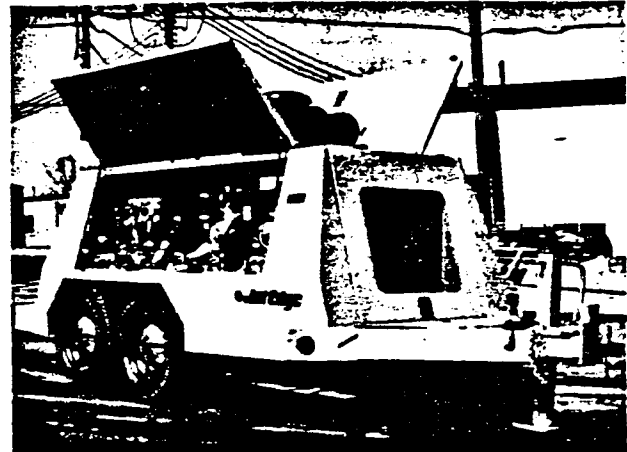
Manual hydraulic pressure and engine RPM. Reliable, construction grade PLC intensifier control assures **smooth, continuous** water flow. Automatic shut down monitors critical unit function. Large ultra pressure gauge offers easy check of operating pressure.

Reliability

Years of research, design and testing have yielded ultra-high pressure pumps with the best **reliability** in the business. By using the highest quality materials and components, machine up-time is maximized.

Stream Quality

Our integrated system design concept and technically advanced controls monitor system functions to provide constant stream pressure **free of fluctuation**. This delivers the **most coherent waterjet stream** producing the highest quality, most productive waterjet available.



Long Life

All models of ultra-high pressure pumps use specially designed **patent pending** poppet style check valves and proven **long life ultra-high pressure seals**. Through efficient design, these components can be quickly and easily renewed. A unique indicator system monitors power unit components assuring continued production time. Full flow filtration insures **extended life** for all hydraulic components. Water to oil (air to oil on 536 series) heat exchanger controls oil temperature contributing to long component life.

Intensifier

- Totally CAD engineered for clean logical layout
- Simple tie rod construction
- Electronic actuation for smooth water pressure delivery
- Proven extended life seals
- Patent pending long life check valve design
- Components easily accessible
- Highest quality stainless steel components
- In-line high capacity attenuator

Hydraulics

- Axial piston, variable displacement, pressure compensated pump
- 5 micron full flow filtration with visual condition indicator
- Off the shelf major components and seals yield fast field service and low operating expense
- Neat, clean logical plumbing layout
- Electronic control and protection
- Mechanical Hydraulic gauge

Motor and Electrical

- Cummins L-10 250 hp diesel engine
- 40, 100 and 200 hp high efficiency electric motor
- 1780 rpm o.d.p. 60 hz standard
- Wye Delta soft start with disconnect standard
- 460 VAC 3 phase
- Door Safety interlock
- Control power, step down transformer 24 VAC
- Isolated, control panel mounted emergency stop button
- Hour meter

Controls and Instrumentation

- Automatic system protection shut down
- Rugged industrial/construction rated programmable logic control
- Environmentally sealed control panel
- Fault condition shown with indicator
- On-line System diagnostics
- Modular electronic component design
- Over cycle protection
- Low inlet water pressure shut down
- Pressure bleed down

Construction

- Rugged all steel welded framework and access panels
- Hinged cover and removable panels for easy access
- Integral hydraulic reservoir
- Sound insulated for quieter operation
- Attractive Design
- Attention to Details
- 536 towable with 3/4 ton pickup truck
- Heavy duty reliable surge brakes
- Large fuel tank (when required)

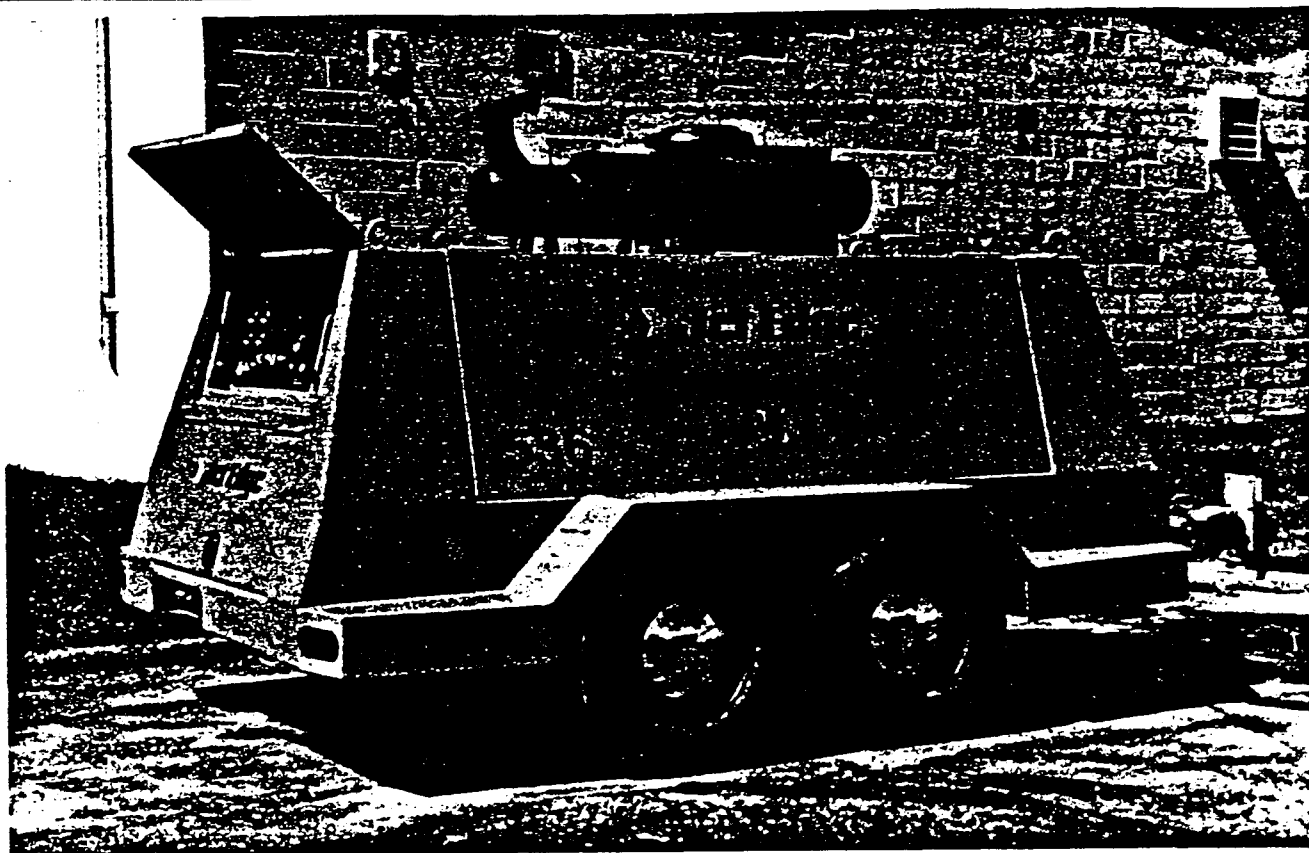
Options

- TEFC rated motor
- Alternate voltages 230 380/50 hz, 575 VAC

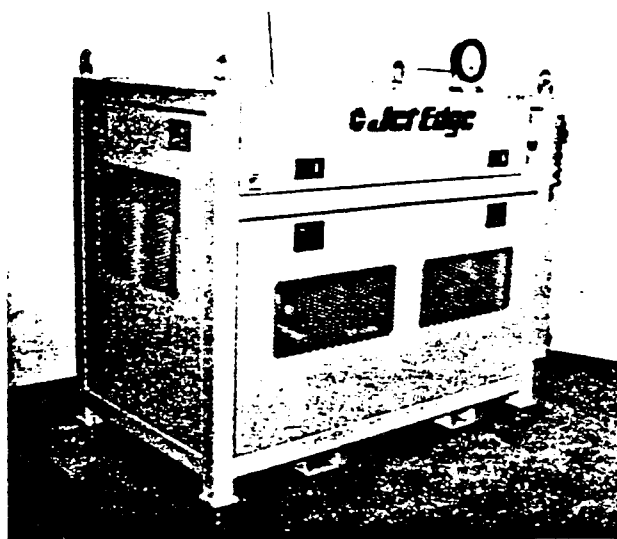
	40 HP	100 HP	200 HP	250 HP
Model Number	136E	336E	536E	536
Intensifier Type	Single	Dual	Dual	Dual
Ratio	12:1	12:1	12:1	12:1
Continuous Output Pressure (psi)	36,000	36,000	36,000	36,000
(mpa)	248	248	248	248
Strokes per Minute	60			
Flow (gpm)	1.2	3.3	5.5	5.7
Hydraulic Pump	Open Loop		Closed Loop	
Oil Cooling	Shell & Tube Water Over Oil		Air Over Oil Radiator	
Auto Bleed Down	Manual Standard Auto Optional		Standard	
Motor Speed (rpm)	1780			2100
Type	ODP			N/A
Attenuator Capacity	.5 gallons (1.89 liters)			
Full Load Amps @ 460 VAC (60 hz)	52	128	240	Cummins Diesel
op 230 VAC (60 hz)	104	256	—	N/A
op 575 VAC (60 hz)	41	102	192	N/A
Motor Starter Type	Standard Wye-Delta			N/A
Weight	2,200	3,600	7,800	8,500
Width	36.0 in	35.0 in	85 in	85 in
Length	72 in	88 in	188 in	188 in
Height	55 in	48 in	82 in	82 in
Water Inlet Pressure	60 psi			
Water Filtration	1 micron			
Hydraulic Accessory Port	2.5 gpm @ 1,500 psi		5 gpm @ 1,500 psi	
Air Compressor	N/A		13 cfm @ 100 psi	



Mobile Ultra Pressure Intensifier Pumps



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Telephone 612-545-1477 • 800-JET EDGE • FAX 612-545-5670



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Surface Preparation/
Hydrodemolition**

Waterjet Technology at Work

"City workers prefer waterjetting to traditional maintenance methods. Hydrodemolition is the tool of the future."

Situation

Concrete bridge decks suffer from spalling, cracking and pop-outs. Concrete road barriers are scaling and flaking, and must be cleaned and re-sealed. Both suffer chloride (road salt) damage.

The City of Minneapolis has used traditional maintenance tools that can damage non-deteriorated material and create environmental problems. The use of air-hammers on deck surfaces destroys good concrete because of limited operator control. Impact tools also create strong vibrations, causing steel re-inforcement to break its bond from good concrete, some distance from the point of impact. Sandblasting concrete barriers causes environmental concerns. Airborne dust and particulates present danger of silicosis.

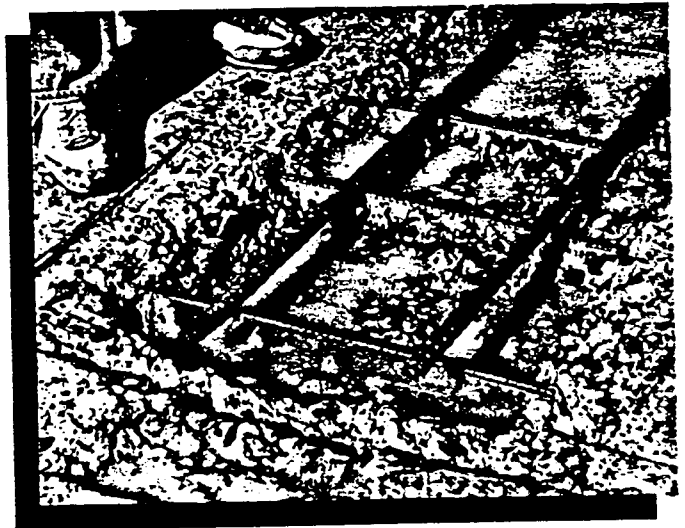


With water supplied by the hydrant at right of the Jet Edge mobile power unit, a Minneapolis bridge deck is prepared for an overlay. The deteriorated concrete is waterjetted at a pressure of 36,000 psi. Operator can extend the flexible water hose up to 150 feet from the power unit without loss of pressure. The clean operation creates no dust; the clouded area is water vapor.

Remedy

The Bridge Maintenance Department has used a Jet Edge 536 mobile power unit with two Ultra-Lite lances to refurbish decks and barriers. Easily towed by pickup truck between jobsites, the power unit provides 36,000 psi of water pressure to the

John Beetsch
General Foreman
Bridge Maintenance Department
City of Minneapolis

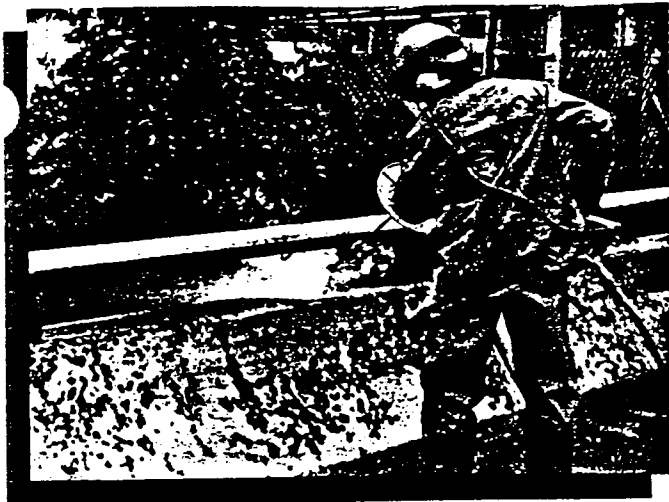


Deteriorated concrete has been waterjetted with no damage to re-inforcing steel which has been cleaned of scaling. When necessary, a concentrated water stream can cut cleanly through re-steel rod bar. Notice the excellent rough bonding edges left by the waterjetting system in preparation for new concrete.

operators' lances. Using either a city water truck or water hydrants where available, work crews say waterjetting achieves fast, clean results. The system creates an excellent, rough bonding surface for new concrete or asphalt overlay. Water is consumed at a low six gallons per minute.

"The system removes only the deteriorated material," says John Beetsch, general foreman. "With jackhammers, you destroy too much good concrete. This makes repair costs higher."

The precise directional ability of the lances enables concrete removal without damage to re-inforcement steel. Their light weight improves production with less operator fatigue than associated with impact tools, and the absence of vibration avoids the danger of the re-steel breaking its bond with good concrete. City workers discovered that the system provides a "feel" for sub-surface deterioration that can't be detected



Scaling and flaking is removed from concrete barrier on this bridge over the Mississippi River. Where no hydrant is available, a city water truck supplies the Jet Edge system at a rate of only six gallons per minute. By waterjetting, the city avoids the clean-up of residual grit left by sandblasting.

with impact tools. The waterstream helps locate additional weak spots, and complements the chain-dragging method of detecting loose material or overlay separation.

"We are waterjetting several bridge decks a season," said Beetsch. "The absence of dust and other airborne particulates is a clear benefit to our maintenance crews."

Waterjetting is proving equally effective for the City of Minneapolis in performing surface preparation for re-sealing concrete barriers. The system is proving faster and less costly than sandblasting. Scaling and flaking is efficiently removed, and the water stream washes out the corrosive chlorides used extensively in Minnesota.

"There are no clean-up problems associated with waterjetting," Beetsch said. "With sandblasting, you need a bucket loader and one or two additional workers to clean up the grit."

Production has averaged 800 square feet per eight-hour day on the Jersey barriers that are 3 feet high with a top thickness of 1 foot.

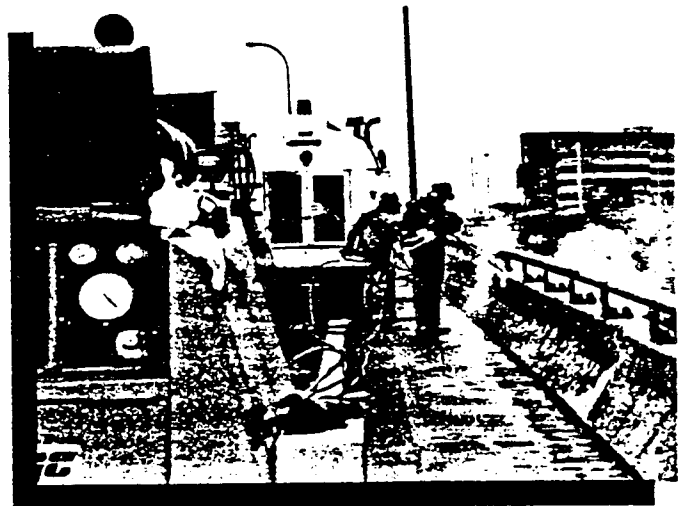
The city is using a three-man crew on the decks and barriers; one operator controls each Ultra-Lite lance, while a third crew-member moves traffic barriers, and performs occasional operator relief duty. City workers were thoroughly trained by Jet Edge specialists.

The City of Minneapolis is exploring other uses for waterjetting that include overhead work on bridge

beams, piers and abutments. Also being considered is the hydrodemolition of selected full-depth concrete sections. Waterjetting with the Jet Edge system has the capability of cutting through concrete up to 2½ feet thick, including the embedded steel.]

Jet Edge provides a maintenance tool for road and bridge rehabilitation with a cutting edge that does not wear out. Its absence of heat precludes the danger of spark ignition where volatile solvents or explosives may be present. And waterjetting has the capability of cutting virtually any material without the release of airborne contaminants.

"Waterjetting," says Beetsch, "is drawing interest on our city projects from state and county officials. And private contractors who drive by our jobsites have stopped to make inquiries. Hydrodemolition, in my estimation, is the tool of the future."



With a strict safety code, the City of Minneapolis equips its waterjetting crews with hardhats, face shields, ear protection and rainsuits. This crew averaged 800 feet in an eight-hour day of barrier clean-up prior to re-coating.

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Coating Removal/ Surface Preparation

Waterjet Technology at Work

"I'm very
optimistic . . . this
could be the greatest
thing for our industry."

Bob Wiplinger
President
Wipaire, Inc.



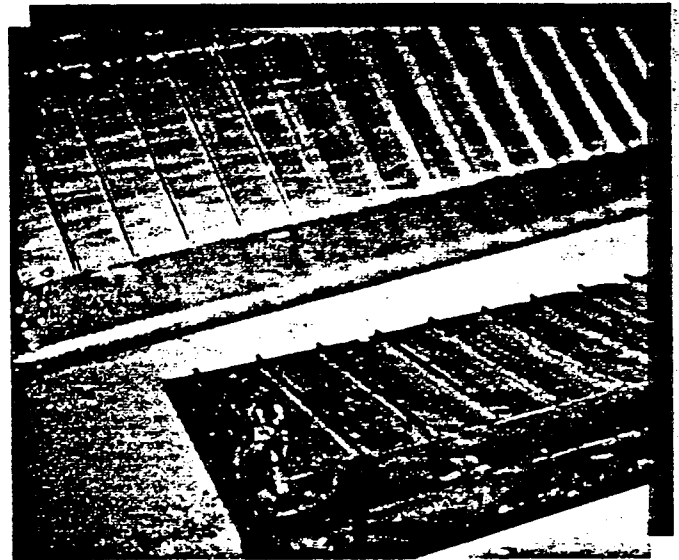
Situation . . .

Light aircraft rebuilder/refinisher is discouraged from chemically stripping paint from aluminum by EPA regulations. Other paint removal methods (plastic bead blasting, sand blasting) degrade the aircraft's finish while inducing stress in the aluminum. Other ramifications of these methods are loosening of rivets and stretching of the aluminum.

Remedy . . .

Wipaire, Inc., the largest manufacturer of floats for light planes is also the only restorer/modifier of the popular single-engine Beaver. "The Beaver is the best 5,000 to 6,000 pound class seaplane made," according to Bob Wiplinger. Most of these planes were manufactured in the 1950s providing a brisk business for Wiplinger in the restoration and upgrading of these aircraft. "We get these planes in with any of three types of paint — polyurethane, enamel or lacquer. The toughest to strip is the olive drab military lacquer," explains Wiplinger.

Because of the EPA regulations regarding the disposal of chemical paint strippers, Wiplinger discontinued stripping paint and jobbed the paint removal out to shops hundreds of miles from his facility at Fleming Field in South St. Paul, Minnesota. Wiplinger was aware of waterjet cutting in aircraft manufacturing, and was interested in applying this technology to paint stripping. After contacting the Jet Edge factory, Wiplinger was convinced the method was viable for his operation and obtained a Model 536 Mobile Power Unit equipped to provide 36,000 psi ultra-high pressure water spray through two hand held lances. By holding the fan-tipped lances $\frac{3}{4}$ " to one-inch from the aircraft's surface, operators have been successful in stripping the relatively soft aluminum of paint. Also, the directional agility of the waterjet allows Wiplinger's crews to remove glues and sealers in confined areas of the airframes and floats. The



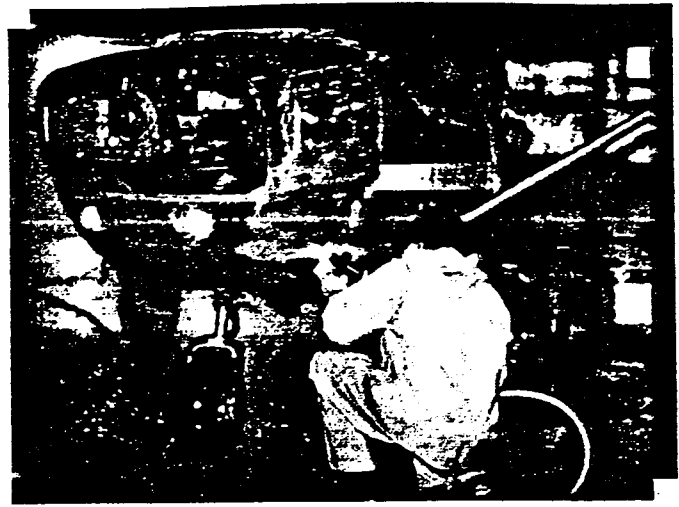
Aircraft components shown before and after stripping with the Jet Edge method.

power unit is supplied by a garden hose and uses only three gallons of water per minute to strip 100 percent of the paint. The resulting finish is ready for primer and paint. This eliminates a cleaning step that must be done even after chemical stripping which leaves a film. "We can strip a plane with the Jet Edge as fast as the chemical method but without the mess and hazardous fumes. Now we just deal with the paint disposal not the chemicals and that is a lot easier," Wiplinger notes. "My operators prefer the waterjet and I'm very optimistic . . . this could be the greatest thing for our industry." Wipaire is stripping paint from aluminum down to .020-inches thick. An independent laboratory — Twin City Testing — has verified that the ultra-high pressure as applied by Wipaire is not detrimental to the metal.

The Jet Edge waterjet stripping has encouraged Wiplinger to expand his business. Plans call for a two stall 120' x 185' stripping/painting facility with a hoist to raise the planes for easier underbody waterjet stripping.



One hundred percent paint removal is accomplished using a fan-tipped lance.



Model 536 Power Unit is attached to a conventional garden hose and powers two lances with 36,000 psi water pressure.

Equipment . . .

- Model 536 Mobile Power Unit
- 2 Jet Edge Ultra-Life Lances
- Standard fan tip orifice mount
- Fan tip size .018"
- Local water supply

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Wooden jigs support aluminum components for rapid paint stripping without damage to the plane's finish.

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Coating Removal/ Surface Preparation

Waterjet Technology at Work

"This is the toughest work we do, only ultra-high water pressure can remove this paint build-up."

Al Schafer
President
Midwest Waterblasting Co.

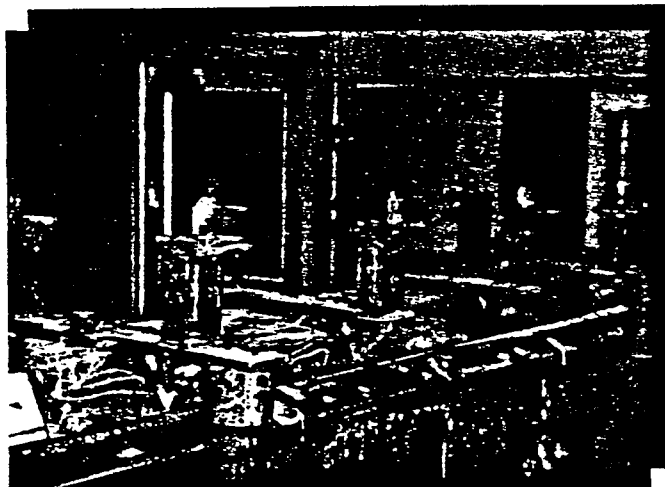


Situation . . .

Bumper carriers in a large automotive plant are covered with high resin, polyurethane paint of up to 1½-inches thick. The excess build-up causes problems in operation of the conveyor system and positioning of the robotic spray guns.

A highly elastomeric material, high resin polyurethane is one of the toughest paints to remove. Solvent removal methods are ineffective because release agents are absorbed by the compression of the paint. Disposal of the solvents is also an expensive proposition.

There are a total of 370 carriers on the conveyor line — each carrier handles four plastic bumpers. The plant shut down over the Labor Day weekend in order to clean the carriers in time for a return to production in three days.



Operators used four hand held Jet Edge Lances hooked up to two Model 536 Mobile Power Units. The power units supplied 36,000 psi water pressure to each lance for 62 continuous hours. The ultra-high water pressure easily cleaned the bumper carriers to the bare metal.

Remedy . . .

Al Schafer, president of Midwest Waterblasting Company in Tecumseh, Michigan contracted ultra-pressure waterjet cutting equipment from Ultra Cleaning Systems Inc. of Detroit, Michigan.

Two Jet Edge Model 536 Mobile Power Units and four Jet Edge Ultra-Lite Lances were brought in to do the job. The equipment was set-up and run non-stop for 62 hours.

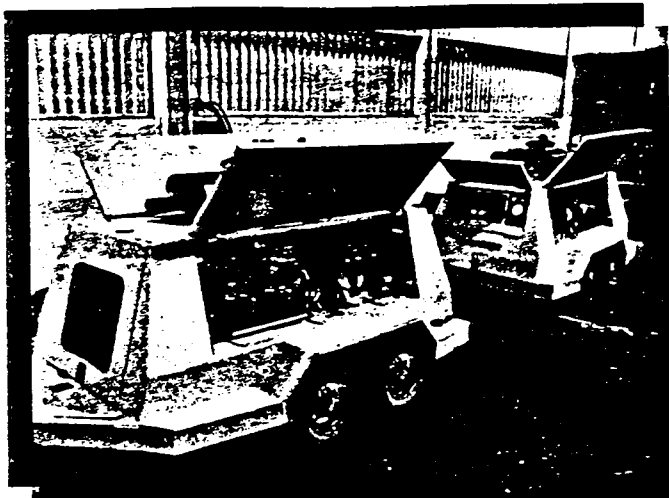
Fed by the on-site water supply, the power units provided 36,000 psi of water pressure to the four lances. The ultra-high pressure easily cut through the 1½-inch thick paint build-up, cleaning the carriers to the bare metal.

"This is the toughest cleaning work we do," stated Al Schafer. "Only ultra-high water pressure could remove this paint build-up."

Since beginning business in 1978, Al Schafer's business growth has been approximately 25% per year. Now through the use of Jet Edge equipment, he believes that growth rate will increase tremendously.



The 1½-inch thick build-up of high resin polyurethane must be removed from 370 bumper carriers in the conveyor line of a large automotive plant within 62 hours. The photo above illustrates the condition of the bumper carriers prior to cleaning.



The two Jet Edge diesel-powered mobile power units.



Operators removed the paint build-up without the environmental concerns normally associated with sandblasting or chemicals. The fogging in this photo is simply water mist from the lance.

Equipment . . .

- 2 Jet Edge Model 536 Mobile Power Units
- 4 Jet Edge Ultra-Lite Lances
- Standard orifice mounts
- Orifice size .027"
- Local water supply

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There are four plastic bumpers placed on each carrier and a total of 370 carriers in the complete conveyor line.

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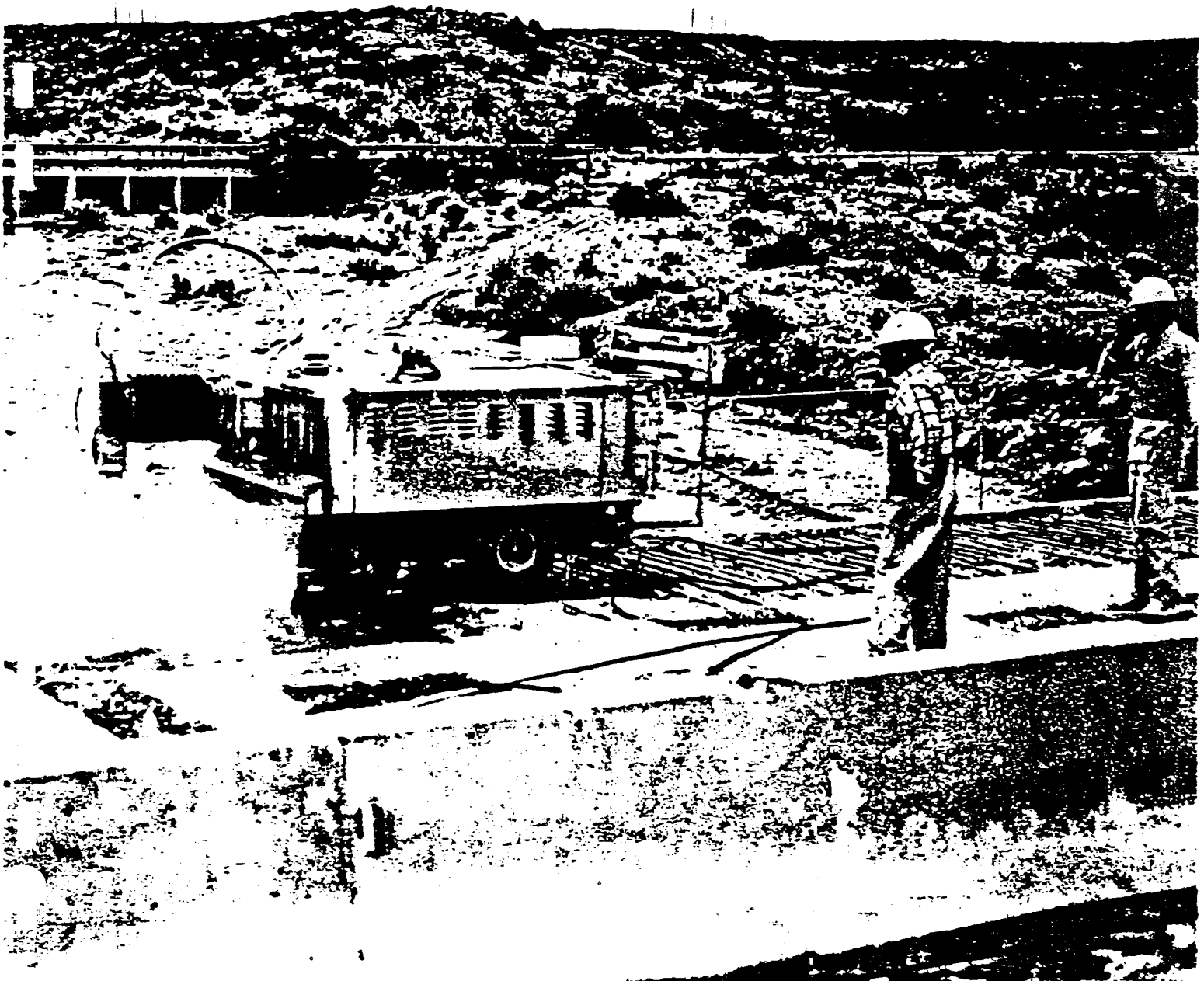
Jet Edge, Inc. 825 Rhode Island Ave. So., Minneapolis, MN 55426 (612) 545-1477 1-800-JET-EDGE

**Hydrodemolition/
Coating Removal/
Surface Preparation**

Waterjet Technology at Work

*"I will do as much, or
more, work with one
Deck Jet and two men
as a 12-man chipping
crew will do."*

Cap Beadle
Waterjetting Contractor
Albuquerque, NM



Rotary waterjet at 36,000 psi effectively removes spalled, laminated or cracked concrete.

A New Mexico contractor is demonstrating to state highway maintenance officials that hydrodemolition of deteriorated bridge decks is faster and more cost effective than demolition with traditional impact tools.

Albuquerque waterjetting contractor Cap Beadle sold a successful distributorship for a major line of diesel engines, then spent a year studying a growing technology he describes as "the accepted method of the future." In waterjetting, Beadle has launched a new career and the state of New Mexico is realizing solid cost savings in bridge deck repair.



The Jet crew consists of operators Dean Holstien (left), Roger Daniels (right) and owner Cap Beadle.

Waterjetting replaces chipping crew

Equipped with a Jet Edge 536 power unit and Deck Jet Robot, Beadle recently brought in a two-man waterjetting crew to complete a deck project started by a 10-man chipping crew (plus foreman and equipment maintenance man). The crew had required three working days to complete only 16 square yards of deck removal with chipping hammers.

To complete the job on schedule, the contractor called on Beadle's two-man waterjetting crew to replace the chippers.

The result: The project was completed in only five days as the Deck Jet selectively demolished a remarkable 294 square yards of deteriorated concrete! Results could have been even more impressive had the contractor not been required to patch the demolished sections each day with a fast-setting concrete to open a lane for traffic, thus shortening the time spent on actual demolition.

The Deck Jet Robot: How It Works

A self-propelled, programmable machine designed for selective hydrodemolition, the Deck Jet directs ultra-high water pressure to selectively remove spalled, laminated, cracked or deteriorated concrete. The Deck Jet first defines the length and width of the removal area, as well as the increment indexing. The defined area may be modified on the fly. Set-up is fast and simple, requiring only water hook-ups to begin operation.



Selective removal is the key to cost-effective bridge deck repair. Deteriorated concrete is removed quickly with the waterjet without damaging rebar or the good concrete.

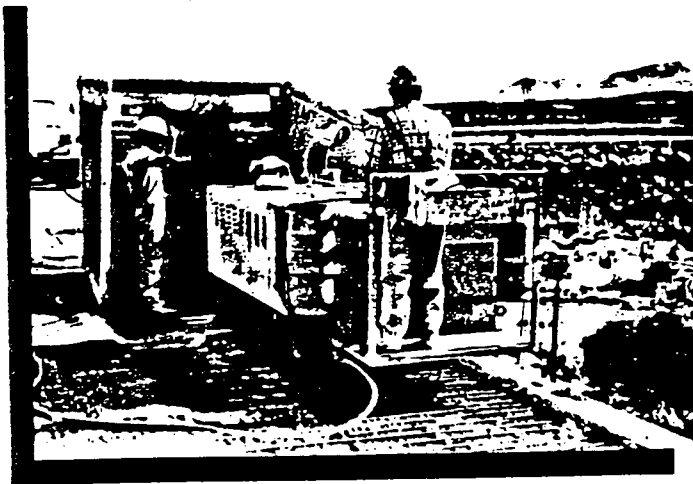
Water consumption is an extremely low 6 gpm allowing available water sources to be used. The Jet Edge power unit provides 36,000 psi of ultra-high water pressure to the Deck Jet from the unit's powerful intensifier-type pump. The Deck Jet incorporates a rotary waterjet nozzle for more effective demolition. After deteriorated concrete is identified by chain dragging, Beadle begins

his waterjetting operation by making a test pass over a deck section to determine the extent of deterioration and the nominal machine speed to obtain optimum results. This pass removes a top layer of concrete, and frequently satisfies all of the material removal requirements.

Beadle emphasizes that the Deck Jet is the superior machine for **selective** hydrodemolition. It is also the lowest cost hydrodemolition package in the industry.

Selective Removal Is the Key

"Our work is primarily patching areas damaged by water and salt," Beadle says. Although the state allows only 15-lb. chipping hammers to limit the damage to good concrete, the hammers, nevertheless, have created microfractures and caused damage to re-inforcing steel bars. And the hammers also can cause re-bars to break their bond with good concrete away from the point of impact."



Repositioning the self-propelled Deck Jet is easily accomplished for programmed demolition of a deteriorated portion of the bridge deck. Shroud contains debris from the waterblast process.

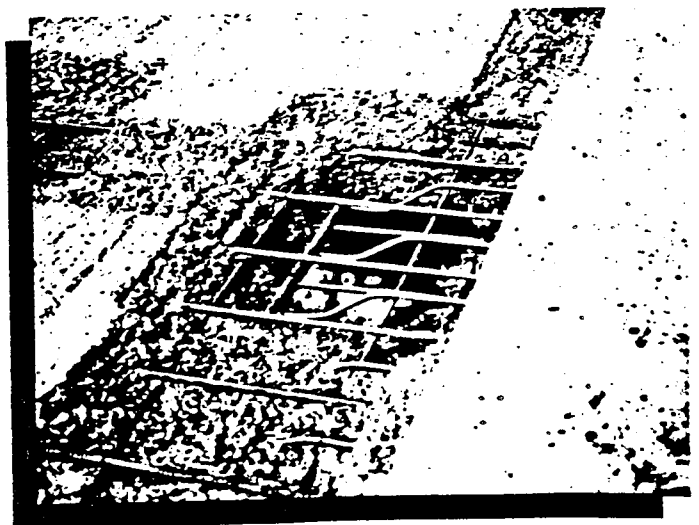
By selectively waterjetting only the deteriorated concrete, the state avoids costly overkill from the loss of undamaged deck sections caused by impact tools or equipment designed for total deck demolition. Beadle cites an example where a competitive hydrodemolition machine—

operating at only 15,000 psi of water pressure and intended for total deck demolition—not only proved extremely costly in replacement concrete, but required two tankers to dispose of the water. The machine is operated at an extremely high volume rate of 40 gpm.

"If a deteriorated area is as small as a square foot, we can program the Deck Jet to take just that amount," Beadle says. "Our experience has shown that on the average bridge deck only 35 percent has to be removed. Water use at 6 gpm is extremely low, and about one-third of it evaporates almost immediately."

The Deck Jet is precise in its removal capabilities, and Beadle appreciates the machine's ability to control the depth of removal. Its computerized motion-control system adjusts the waterjets on two axes, side to side and forward and back. While Beadle's crew occasionally must remove concrete to full depth, most demolition work is held at 1 to 3 inches from the surface. With its precise rotating nozzle, the Deck Jet can remove a full 48"x48" deck section in a single pass at any depth required. It also provides "saw quality" edges.

Prime contractor, Bill Hasse, Hasse Contracting Co., Inc., Albuquerque, who retained Beadle's waterjetting service, concurs: "Chipping hammers destroy too much good concrete. Operators have a tendency to overdo it, and if the bond with



In order to save patching costs, full depth removal is accomplished only when necessary.

the re-bar is injured, you can't rectify it. You leave a void where the concrete eventually will crack."

Sharper Bids Mean Healthier Profits

The ability of the Deck Jet to remove less than full-depth concrete means Beadle's contractor customers can accurately calculate lesser amounts of mix needed for patching—a key consideration in making an astute bid. This is significant when you consider the cost of quick-set, latex modified mix at \$500 per cubic yard.

In the past year, Beadle has completed 4,000 square yards of deck demolition with his Jet Edge equipment. Complementing his 536 power unit and Deck Jet, he owns Jet Edge abrasive cutting equipment and hand-held lances, a 2½-ton truck with a 700-gallon water tank, and a 2-ton water-tank truck with 4,000-gallon capacity. The trucks tow the power unit and Deck Jet to jobsites.



Waterjet removes deteriorated concrete in large chunks to speed productivity.

Beadle's crew appreciates the side benefits of the waterjet system. With less dust and operator fatigue, both inherent in chipping hammers, his equipment operator says he can "run the Deck Jet for 20 hours straight" without tiring. And the waterjet "leaves an excellent rough finish for better adherence to the new concrete overlay."

A Wide Range of Jet Edge Opportunities

In addition to his bridge deck jobs, Beadle explored other areas of waterjetting capabilities by performing cleaning and coating removal projects using Jet Edge hand-held waterjet lances. Recently, he removed the coatings from 15 metal shipping containers ranging from 10' to 20' long; removed paint from the top 150' of a 450' stack when the original crew of sandblasters could no longer maintain sufficient air pressure; and cleaned and prepped 45,000 square feet of stucco surfacing on the University of New Mexico's biology building.

Cap Beadle's results have helped re-educate New Mexico highway officials in the efficiency of deck repair by ultra-high pressure waterjetting techniques. That he now holds contracts to refurbish 12 more bridge decks is clear evidence of Cap's capabilities and the advanced technology of hydrodemolition with Jet Edge.

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February 20, 1990

Mr. Wilson McArthur
Quadrex Environmental
P.O. Box 4100
Gainesville, FL 32613

Dear Mr. McArthur:

I enjoyed our brief conversation regarding the requirements for the upcoming operation in Washington. As promised, information on Mecanotron standard products is enclosed herewith. We realize these standard industrial products will not directly address the problems this project presents. However, over 80% of Mecanotron sales last year were for custom design and engineering projects. We would be happy to put this robotic engineering expertise to work for you.

In addition, as we also discussed, I have considerable experience in the area of teleoperated remote robotic systems in hazardous-to-humans operations. The devices designed and used in these operations were the 21st Century Robotics Tactical Support Robots model series TSR700 and TSR70 - commonly known as the "WASP" and "HORNET". A few examples of the operations we were involved in are listed below.

SPECIAL TSR 700 FOR DUPONT SAVANNAH RIVER LABS

The standard TSR was redesigned for this application and converted from a gasoline engine prime power machine to an electric motor prime power (480 volt 3 phase) machine with the power supplied by a reel-controlled power cable. The initial project involved the removal of lead shot from between the double walls of large steel vessels. The robot was used to assist a large remotely operated gantry crane in positioning the vessels and then applied a cutter/grinder to open sections of the vessel walls and remove the lead shot. This robot was subsequently used in other decommissioning projects (see photo of unit enclosed).

STANDARD TSR 700 FOR SAVANNAH RIVER LABS

This standard TSR 700 was designated for use on a decontamination project contracted to Bechtel. In this application, the robot carried a array of rotating hydro-static cutting nozzles contained in a vacuum assembly carried by the robot end-of-arm gripper. This teleoperated robotic system was used to remove 1/4 inch of concrete from the floor of a contaminated area. As a note of interest, this robot was coated with a peelable compound and was safe for use on other projects when the coating was removed and the rubber tires replaced.

Mr. Wilson McArthur
Page Two

TSR 700 PURCHASED BY US ARMY/REDSTONE ARSENAL

This unit was used for the removal and disposal of "dud" TOW and DRAGON Antitank missiles from the live firing range at Redstone, Alabama.

The unit was subsequently returned to 21st Century Robotics for outfitting with a special gripper and specialized crew training for handling of 85 pound canisters of powdered Zirconium. See the enclosed picture of the robot and copies of the "Longhorn Illuminator", the Longhorn Army Ammunition Plant paper, for the program results.

TWO TSR 70 ROBOTS PURCHASED BY SAVANNAH RIVER LABS

These TSR 70 robots (the stair and obstacle-climbing tracked small robot) were purchased for inspection and security monitoring projects. Each unit was capability of carrying eight remotely controlled devices at a time (i.e., counters, dust samplers, etc.) as well as their standard compliment of two CCTV video cameras with pan, tilt, zoom, focus and exposure all remotely controlled. (One unit was equipped with a video camera mounted on a telescoping mast that would raise the camera ten feet above the floor level.) The TSR 70 models will pass through a 24 inch opening and are only 24 inches tall as normally configured with a 4 degree of freedom arm. Details of the projects these units are being used on are classified.

BRADLEY FIGHTING VEHICLE TESTING PROGRAM

A TSR 700 was provided to Aberdeen Proving Grounds, US Army, for use on the Bradley Fighting Vehicle Testing Program. The unit would open the rear hatch of the vehicle and remove live ammunition containers from the interior of the machine.

SPECIAL TSR 700 DELIVERED TO
U.S. ARMY/JEFFERSON PROVING GROUNDS

A special TSR 700 was delivered to the US Army Jefferson Proving Grounds that had the ability to lift a 150 pound weight from a hole three feet deep with the weight six feet in front of the robot base. This unit also had a camera mast that would "lay down" and look into the three foot deep hole. The robot performed these tasks as well as others as part of an antitank mine production testing program.

Mr. Wilson McArthur
Page Three

This is a sampling of the experience gained during a four year period of utilization and design modifications with the basic "WASP" and "HORNET" units.

Also enclosed is an article about our experience (along with Gene Silverman and "Surveyor") with the Russians after the Chernobyl incident. It was during the evaluation by the Russians that a surveyor "exploded" from what we understood was unvented gas from the batteries.

In summation, we can make available a great deal of unique, practical experience and we would be very interested in a joint venture or sub-contract arrangement to provide the necessary design capability, devices and operating expertise for use on this project. In fact, a "new generation" of the 21st Century-Sivan Robots has been conceived and should be adaptable for this project.

Please call me if you require additional information. We look forward to being of service to you in the near future.

Sincerely,



Glenn A. Whittington
President/Chief Executive Officer

GAW:bw

US Robots May Aid In Chernobyl Cleanup

Chicago Tribune

Two U.S. robotics manufacturers have reached agreement with the Soviet Union on the possible purchase of a half-dozen mobile robots for cleaning up the nuclear accident site at Chernobyl.

Representatives of the two companies, Advanced Resource Development Corp. of Columbia, Md., and 21st Century Corp. of Norcross, Ga., said Soviet officials will visit each of them this week for demonstrations of their respective machines, both television-operated, remote-control robots.

"They said it was a 99% chance they would buy if the Commerce Department approves," Glen Whittington, vice president for product development at 21st Century, said.

If the proposed sale goes through, U.S. mobile robots would take their place in the Soviet Union alongside a West German machine. The Blocher Moto MF-2, a 3.4-ton tank-like vehicle was lent to Moscow last week by West Germany's nuclear power industry, Collin Stephens, U.S. representative for the firm, said.

When contacted at the Soviet Embassy, Nikolay Bondarenko, scientific attache, would neither confirm nor deny the proposed sale.

"It is too early to comment," Mr. Bondarenko said.

Department of Commerce officials, who say they are prohibited by law from discussing foreign sales negotiations, refused to comment.

But Mr. Whittington, Gene Silverman, president of ARD, and Harvey Meierman, a robotics consultant who arranged the meeting with the Soviets, all exuded confidence over the weekend that the deal would go through.

"In all my years of exporting, I never had anything go through this fast," said Mr. Whittington, who added that he expects the export license

ing documents to be cleared by the Department of Commerce by today.

"It's obvious there is a big intent by the State Department to be as helpful as possible," he said.

Direct negotiations between Soviet officials and private, non-governmental entities have characterized Soviet inquiries for technical aid since the nuclear accident at Chernobyl. The Reagan administration offered help to the Soviet government shortly after the accident was made known, but was refused.

"They seem not to want to deal with government officials," a highly placed government energy specialist said.

The Soviet Embassy officials are scheduled to travel to Georgia Wednesday for a demonstration of the 21st Century Corp.'s Wasp TSR 700, Mr. Whittington said. The Wasp is a 1,600-pound, \$80,000 gasoline-powered maintenance and clean-up robot that, among other things, can spray liquid, gather and package contaminated material, and wash itself down afterward, Mr. Whittington said.

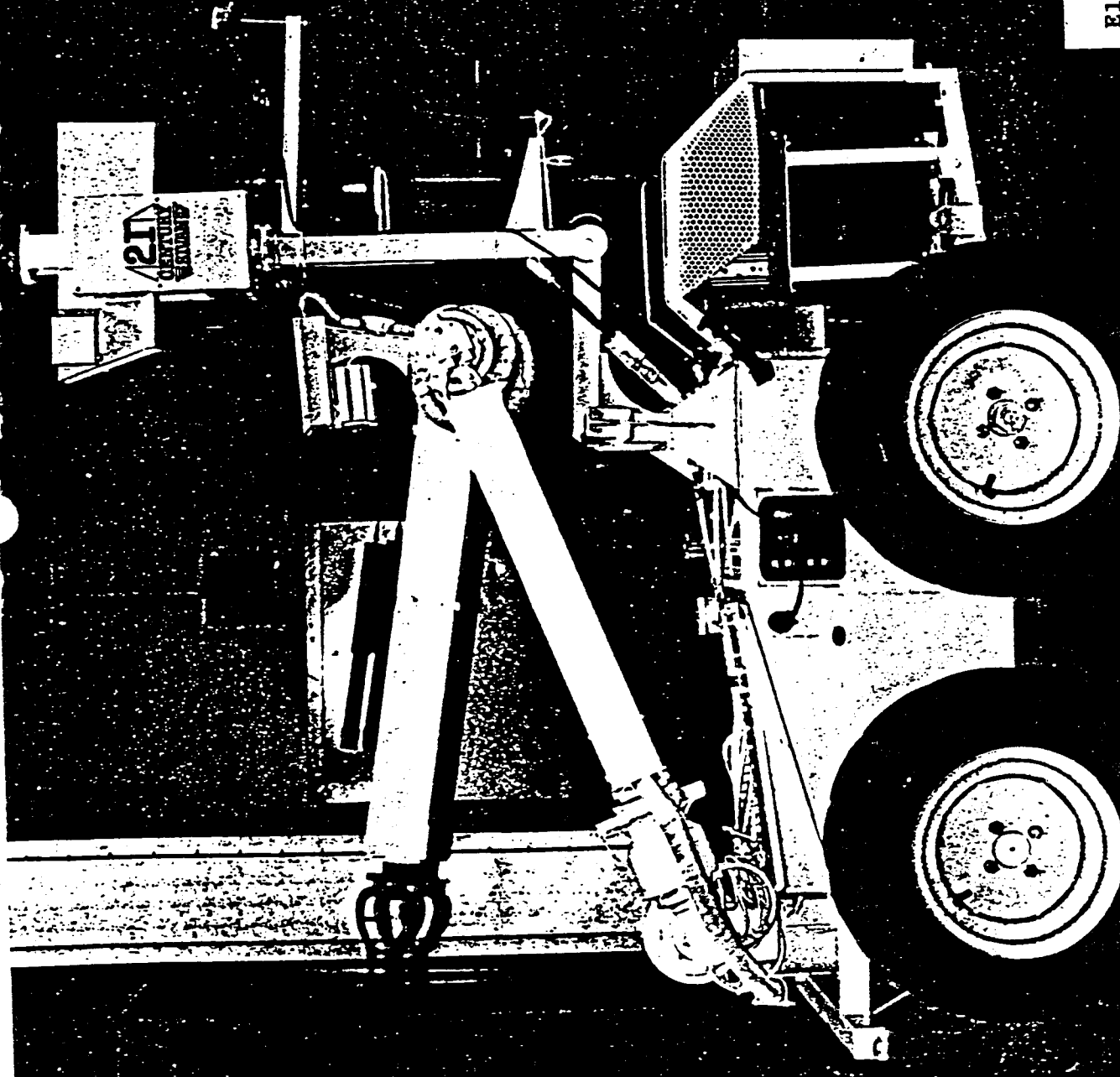
A demonstration will follow in Washington Thursday of ARD Corp.'s Surveyor, a 350-pound, battery-powered, waterproof, radiation-hardened surveillance and inspection robot. The Surveyor can climb stairs, measure temperature, humidity, sound and radiation levels and can provide television and still pictures. Gene Silverman, president of ARD, said. It sells for \$200,000.

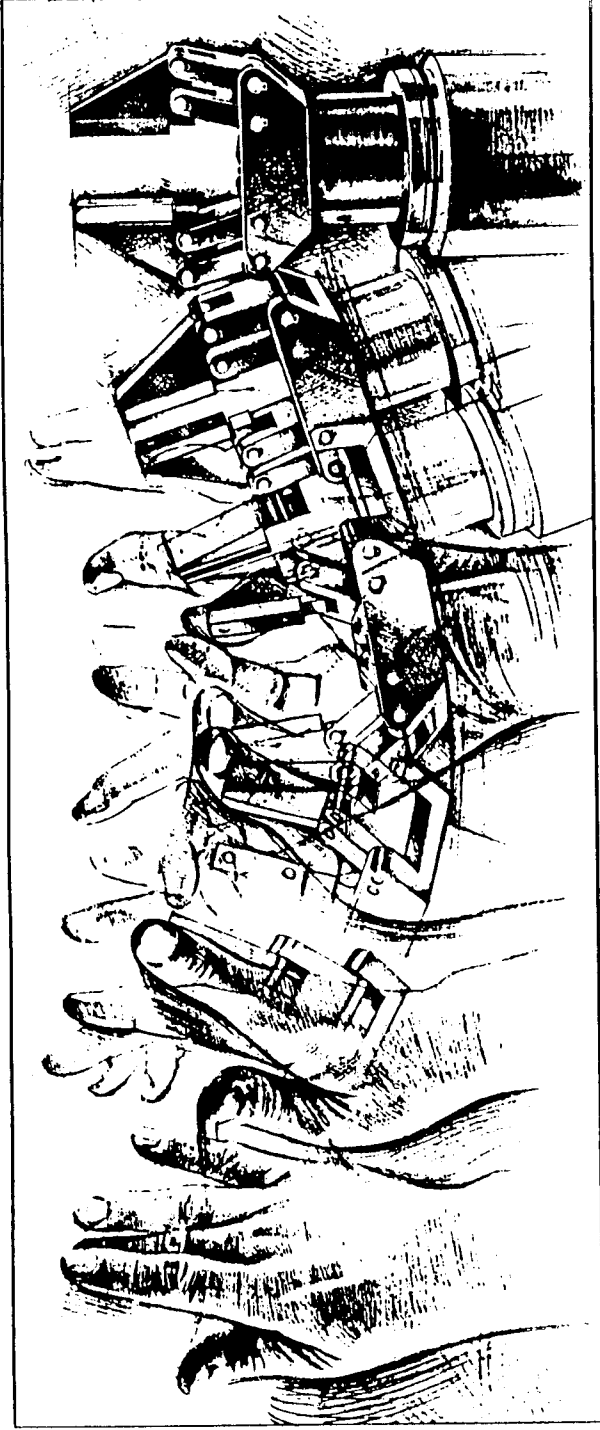
"They want to kick the tires first," said Mr. Meierman, who first approached the Soviets May 9 and said he received a strong indication of interest then. After one subsequent interim meeting, Mr. Meierman said he, Mr. Silverman and Mr. Whittington met for four hours Friday with Mr. Bondarenko and several other Soviet officials.

Journal of
Commerce

Tue, May 20, 1986

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Power Unit
for S.R.L.







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(612) 633-5210

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Two-Finger Pneumatic Angular Gripper	8
Three-Finger Pneumatic Angular Gripper	9
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Flat Linear Actuator True Parallel Gripper	11
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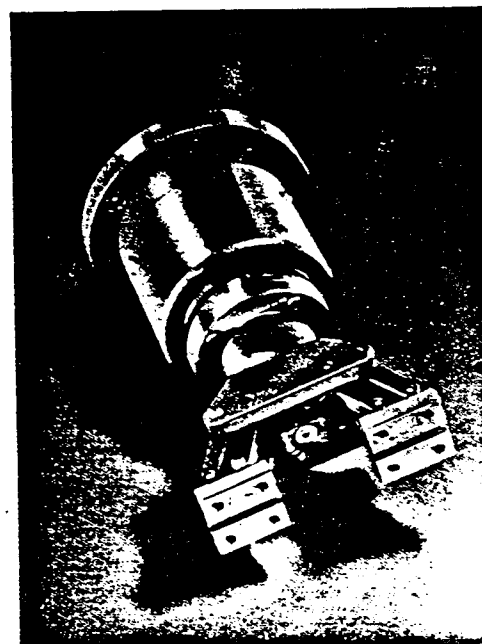
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Brian Dunn, President, C.E.O.



At Mecanotron, our most important product is your satisfaction.

Solving end effector problems for our customers has always been our primary concern. As the use of robotics in industry has expanded and changed, our solutions have evolved into an extensive line of products that meet the needs of a variety of customers. But from the beginning, our primary focus hasn't changed. We are not in business to sell "products" to our customers. We are here to help you find the best solution to your end effector problems. Your satisfaction is our business.

Experience where it counts.

At Mecanotron we bring two very important kinds of experience to the customers we serve. The first is the range of professional skills. Our research, engineering and customer service staffs offer you a truly unique combination of engineering

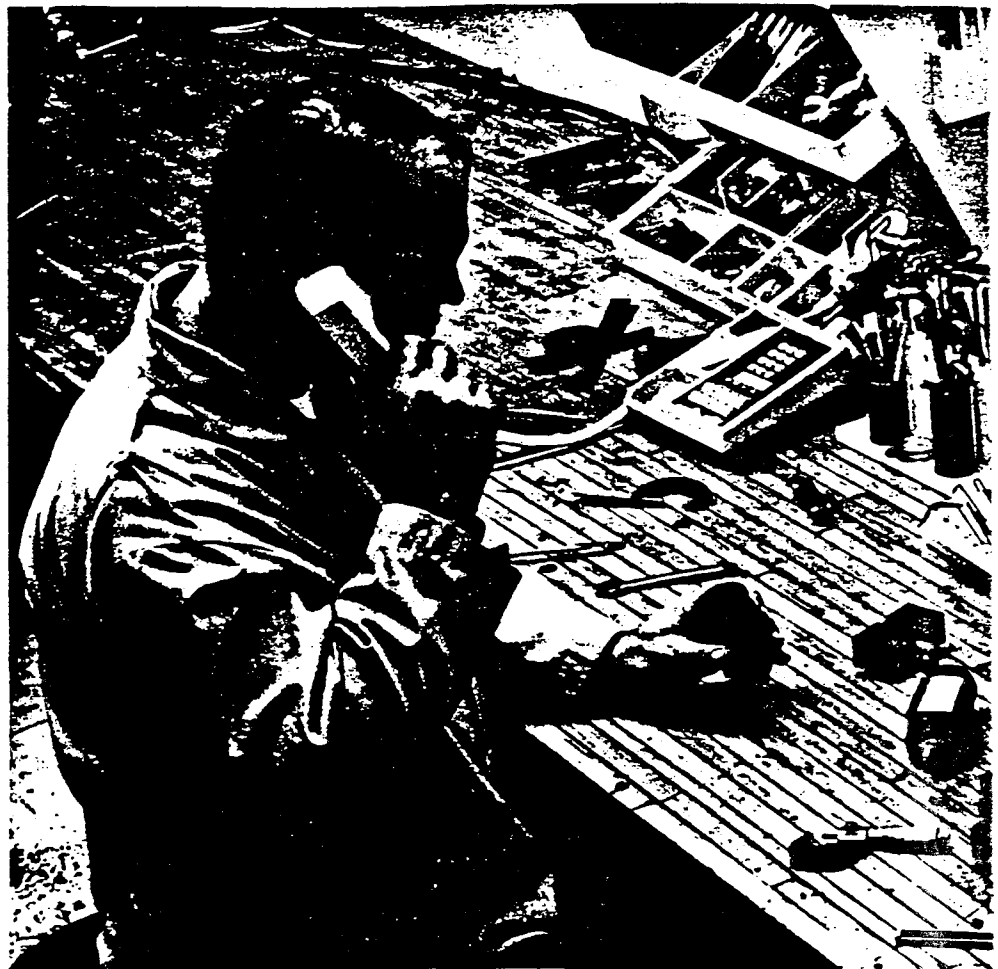
backgrounds which have been supplemented by a wealth of on-the-job experience in a variety of manufacturing and industrial settings. Additionally, our collective experience also includes groundbreaking work done for some of the country's major robotics companies.

Equally important, however, is the experience these staff members have acquired in the process of serving our existing customers in the aerospace, automotive, computer, electronics, package goods and transportation industries. When you talk to someone at Mecanotron, you're talking to someone who has been there. Someone who appreciates the difference between theoretical possibilities and what it actually takes to get the job done in a real world, production environment.

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Hands-on solutions.

The last thing you need to do, or can afford to do, is to reinvent the wheel. If there's an off-the-shelf solution out there, you need to know about it. But the trouble is, almost every end effector application involves a very different set of operating parameters. At a glance, nothing seems to fit your situation. And you know that more often than not, settling for a partial solution will end up costing you far more than you bargained for.

Our approach to solving this complex problem involves a very simple working procedure we follow with all of our customers. It begins with a detailed analysis of your situation and your needs. If practical, we will even ask you to send us a representative sample of the part or parts you want manipulated. In any case, we start by working with you to make sure we fully understand *your* business. Because that is the only way we can help you develop a cost-effective solution that will meet your precise needs.

If a standard product will do the job, we'll recommend it—even if it isn't one of ours. If we can modify one of our existing products to suit your situation, we will certainly suggest it. Only after all of these options have been considered will we ask you to think about a custom design. But if that's what it takes, remember this: Every custom design enjoys the same advantages we have designed into our off-the-shelf products, products with proven workplace performance.

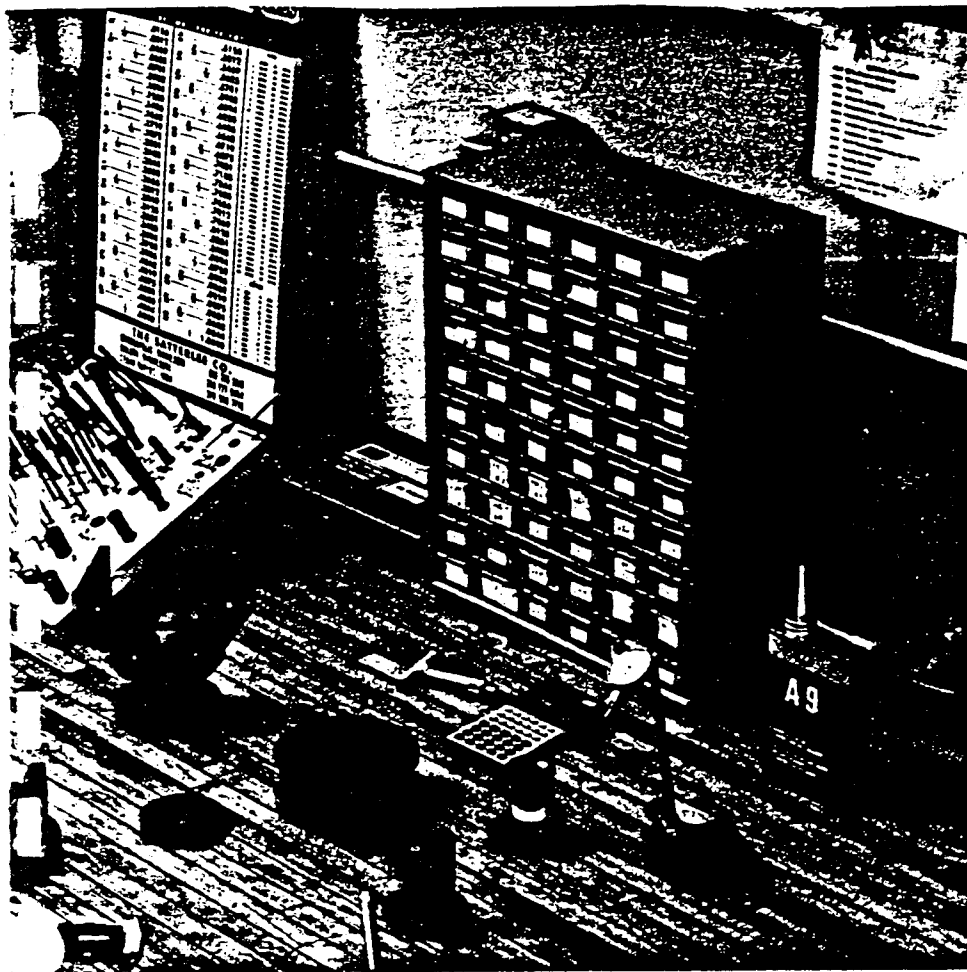
A disciplined approach to the future.

The close working relationship we develop with our customers is what allows us to fully understand their current automation needs. But it also is one of our best resources for anticipating future needs. The development of the next generation of end effectors will, almost certainly, be the result of conversations we are having today with customers who work in a broad range of industrial and manufacturing environments.

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We systematically analyze input from all of our customers in order to focus our research and development efforts on common issues and concerns. At the same time, we track the progress of work being done in a number of technologies and pure sciences. Because we know from experience that the application of this new knowledge is what will allow us to achieve the breakthroughs in efficiency and capacity our customers want and need.

The tests of time and cycles.

If the robotics industry has had a single failing, it is the tendency to promise more than can be delivered. And when you consider the cost of robotic systems, that's a problem no customer should have to live with. You can't afford it. And we can't either.

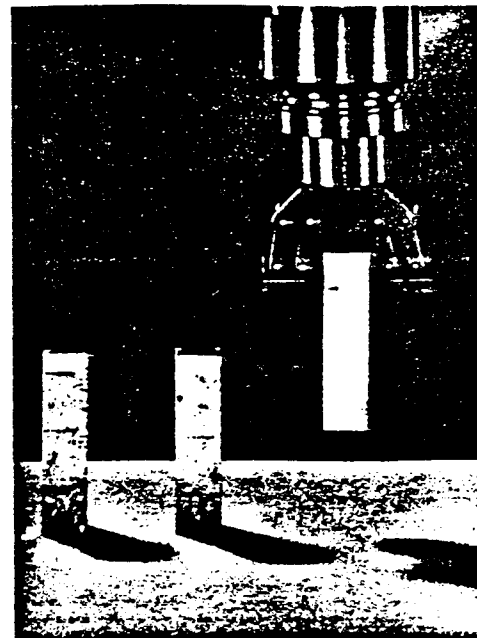
We make all of our customers the same, simple promise. Every one of our products does precisely what it was intended to do. We know this is true because we put each and every product through its paces before we ship it out.

In addition to routine life-cycle testing, *every Mecanotron product we sell is thoroughly bench tested before it goes out the door.* Every product we deliver is 100% bench tested before it leaves our hands. We won't promise you perfection. But we do go out of our way to see that you get what you expect, because *your satisfaction is our business.*

How to get what you want.

End effectors are the one part of a robot or hard automation system that directly interact with the products you make or the process you control. With everything that's riding on the success of your plans, you simply can't afford to settle for anything less than a supplier who is capable of giving you exactly what you want.

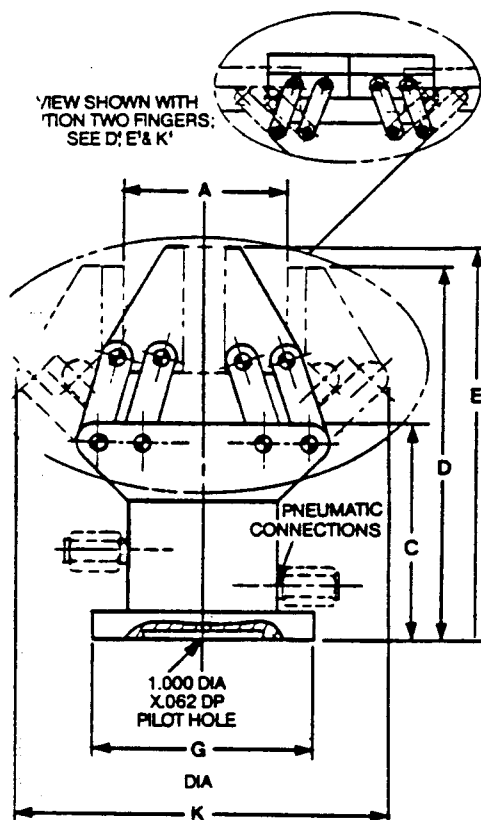
We have the people, the products and the proven experience to help you find solutions to your end effector problems. If you have any questions, all you have to do is give us a call.



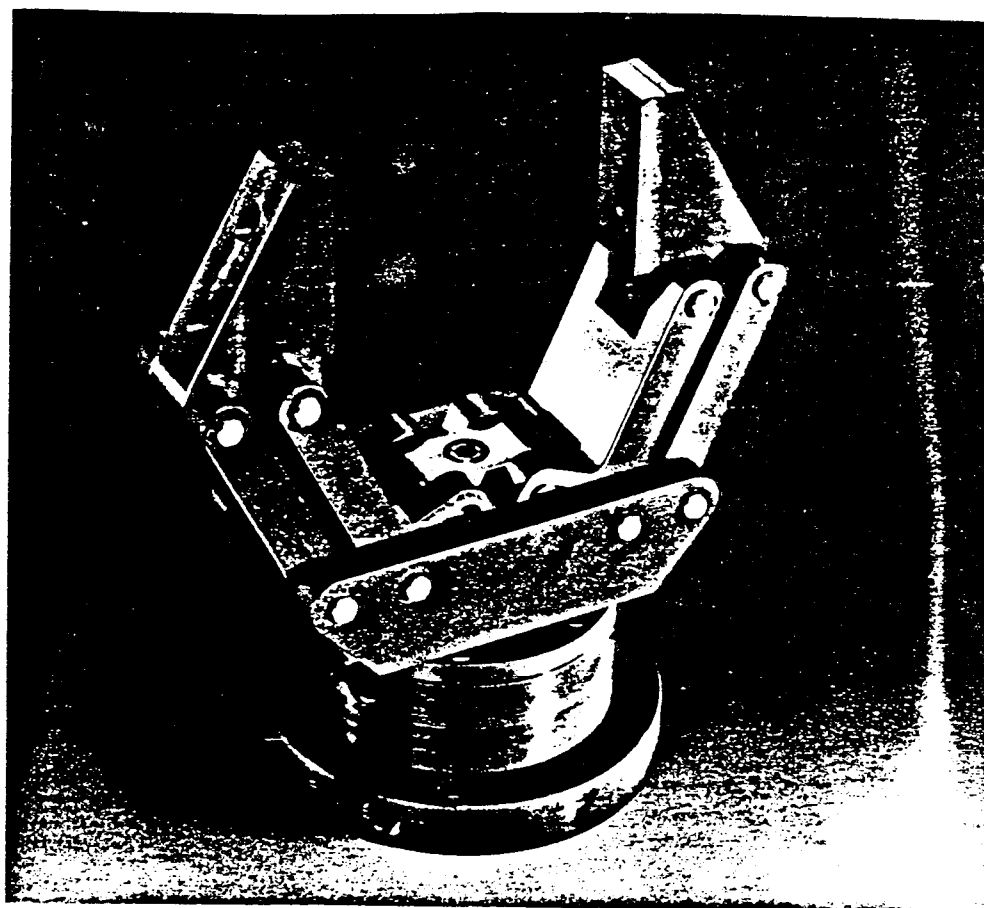
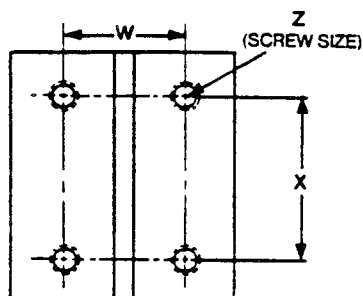
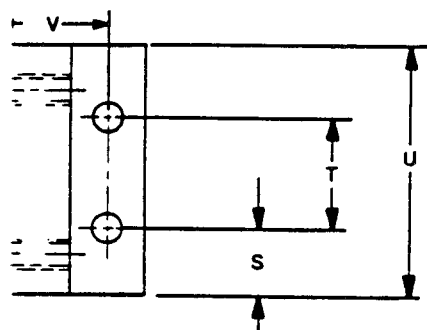
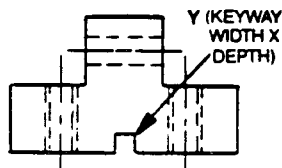
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OPTIONAL
FINGER BLOCKS



EEP-2-384

TWO-FINGER PNEUMATIC PARALLEL GRIPPER – EEP-2

DESCRIPTION:

The arcing parallel motion of this gripper's fingers allows you to utilize the maximum amount of gripping surface at any point during the fingers' entire line of travel.

FEATURES:

- opens/closes in less than a second
- exceptional payload-to-weight ratios
- extensive finger travel range accommodates a variety of part sizes and shapes
- replaceable fingertip inserts may be machined to fit a variety of parts and components
- fingers accept a wide range of sensing options
- thru-body wiring and thru-body pneumatic lines available, when specified, for manifold or tool changer mounting
- smooth, low breakaway motion
- grips internal opposed and external surfaces
- integral linear actuator
- servo valve operation capable when specified
- hard coated, high strength 6061-T6 aluminum withstands harsh environments
- works with Quick Change systems

APPLICATION:

Commonly used in pick and place operations, palletizing or depalletizing, assembly, and machine loading or unloading.

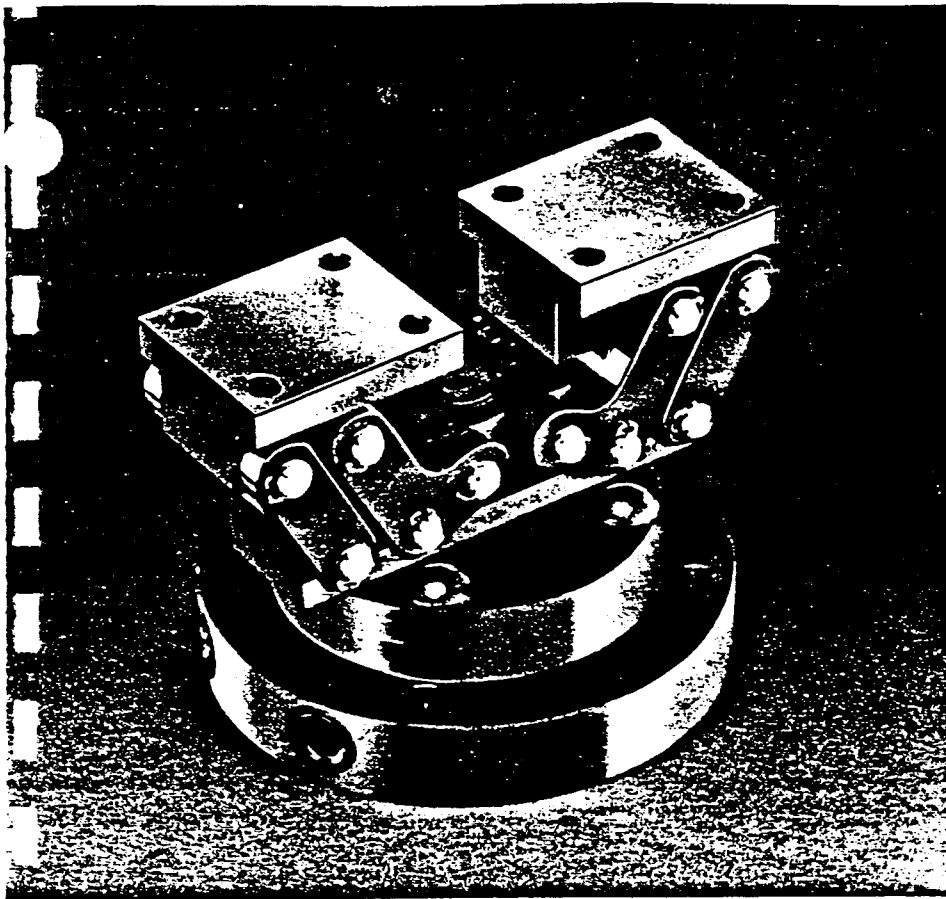
SIZES:

MODEL NO.	A	B	C	D	D'	E	E'	F	G DIA
EEP-2-084	0.625	1.719	1.065	N/A	1.756	N/A	1.825	#8-32	2.000
EEP-2-184	1.625	1.719	1.780	3.094	2.680	3.240	2.812	#8-32	2.000
EEP-2-284	2.000	2.312	2.625	4.892	4.112	5.250	4.312	#10-32	2.750
EEP-2-384	4.000	3.500	3.215	6.812	5.450	7.200	6.812	#10-32	4.000
EEP-2-484	6.000	4.500	4.812	10.312	8.450	10.575	8.575	1/4-20	5.000
EEP-2-584	8.000	6.250	5.575	11.900	9.525	12.825	10.425	1/4-16	7.000

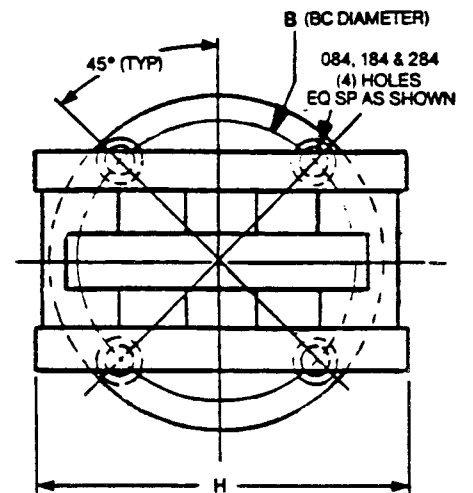
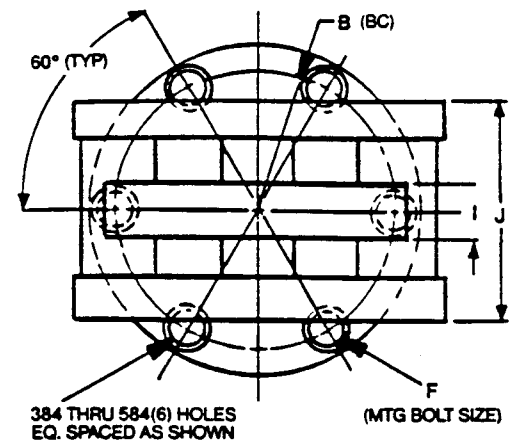
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EEP-2-084



MODEL NO.	H	I	J	K	K'	Grip Force @ 80 psi (LBS)	Weight	Pneum. Connect
EEP-2-084	1.750	.750	.750	N/A	2.250	12	4.2 oz.	#10-32
EEP-2-184	2.375	.375	1.375	3.275	3.640	12	.50 lbs	#10-32
EEP-2-284	3.125	.500	1.875	4.600	5.350	32	1.25 lbs	#10-32
EEP-2-384	4.375	.750	2.250	7.062	7.531	70	3.00 lbs	1/8-NPT
EEP-2-484	6.750	1.000	3.000	10.250	11.000	240	8.00 lbs	1/8-NPT
EEP-2-584	9.500	1.250	3.250	15.250	15.500	335	15.25 lbs	1/8-NPT

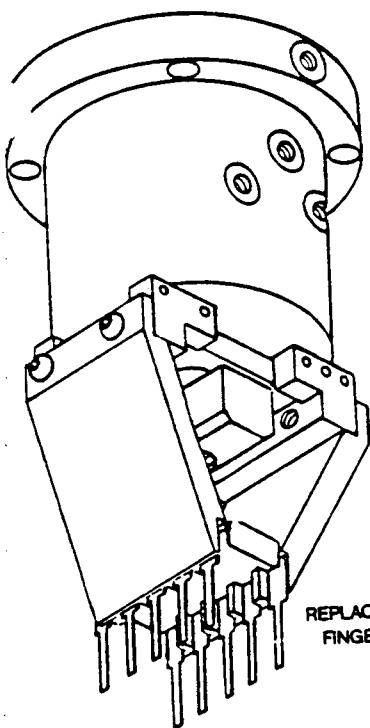
OPTION 2 FINGERS								
MODEL NO.	S	T	U	V	W	X	Y	Z
EEP-2-084	.437	.313	.875	.312	.500	.625	N/A	#6-32
EEP-2-184	.312	.438	1.062	.438	.625	.625	.125 x .078	#6-32
EEP-2-284	.562	.562	1.500	.813	.875	1.000	.188 x .109	#6-32
EEP-2-384	.500	.750	1.750	.750	1.125	1.250	.188 x .188	#10-24
EEP-2-484	.750	1.000	2.500	.875	1.500	1.750	.250 x .250	1/4-20
EEP-2-584	1.500	1.625	3.750	.938	1.625	2.750	.250 x .250	1/4-20

184, 284, 384, 484, and 584 are also available with servo options.

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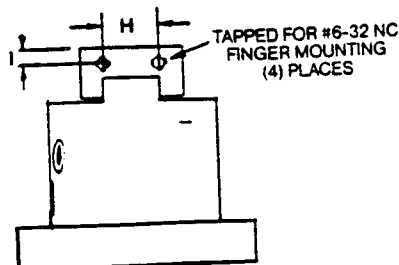
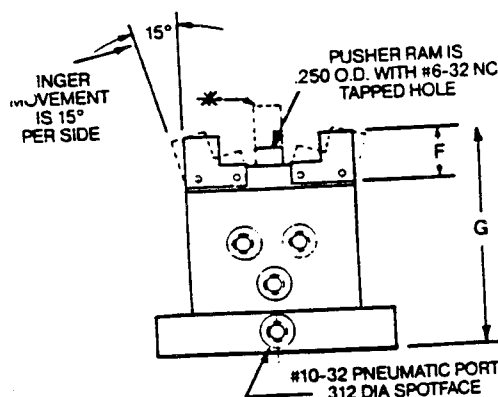
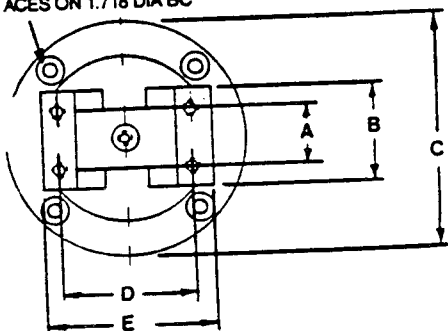
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REPLACEABLE
FINGERS

COUNTER BORED
FOR # 6-32 NC SHCS
ACES ON 1.718 DIA BC



SMT-184

SURFACE MOUNT TECHNOLOGY SERIES – SMT

DESCRIPTION:

Exclusive, double-action design. Parts are gripped with angular finger motion and held while they are moved into position. A pusher rod then inserts the component and the fingers release.

FEATURES:

- low profile
- lightweight design permits larger payloads
- easy fingertip insert installation
- replaceable fingertip inserts may be machined to fit a variety of parts and components
- smooth, low breakaway motion
- integral linear actuator
- hard coated, high strength 6061-T6 aluminum withstands harsh environments
- works with Quick Change systems
- optional vacuum system
- optional parallel finger action

APPLICATION:

Commonly used to perform small parts handling and assembly tasks. Ideally suited for use in automated, electronic circuit board assembly systems.

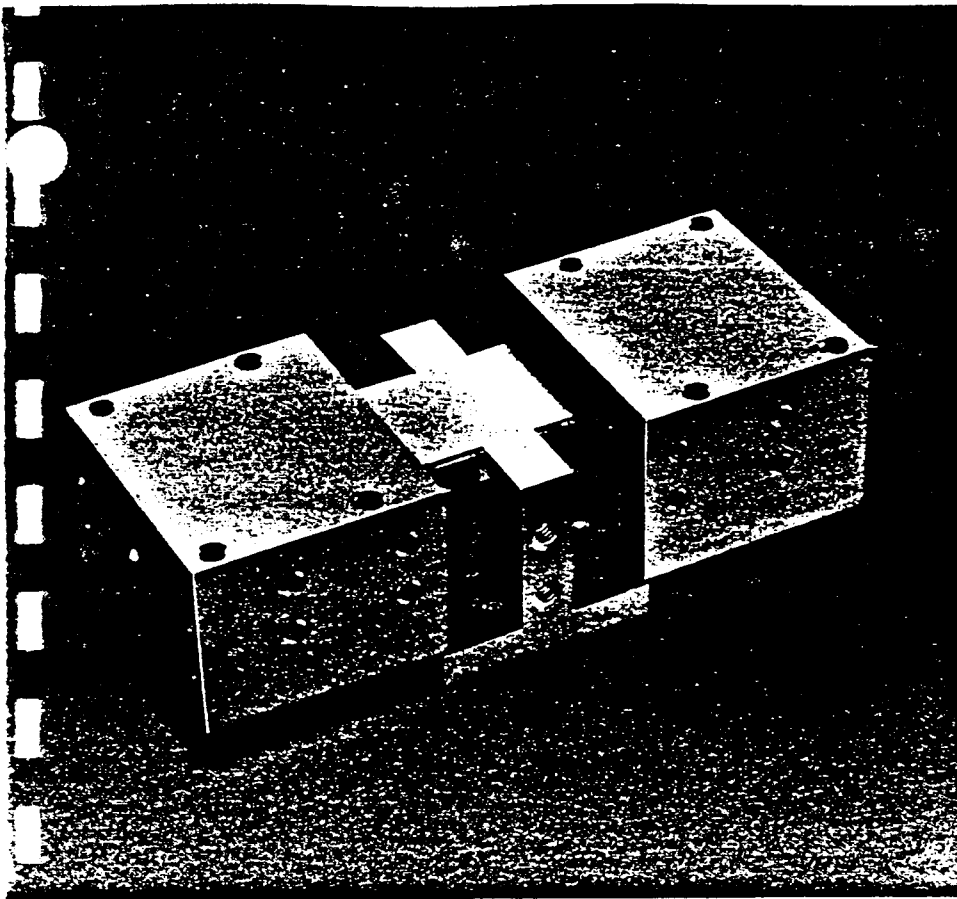
SIZES:

MODEL NO.	A	B	C	D	E	F	G	H	I	WEIGHT
SMT-184	.750	1.000	2.062	1.250	1.500	.500	2.187	.375	.125	6 OZ.

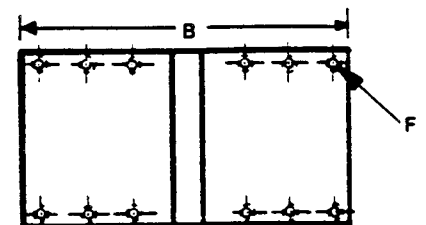
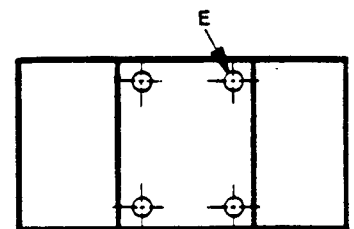
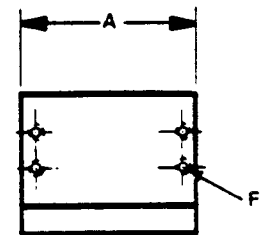
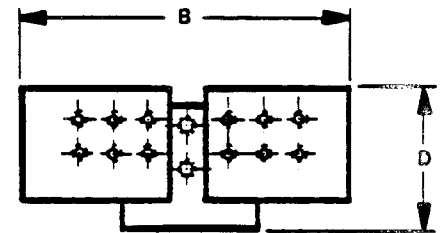
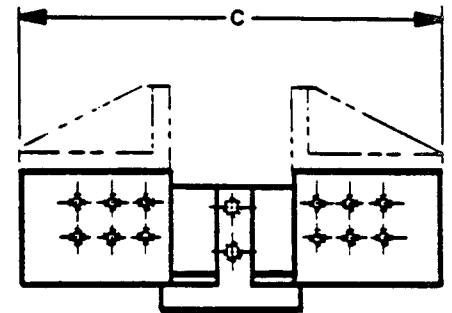
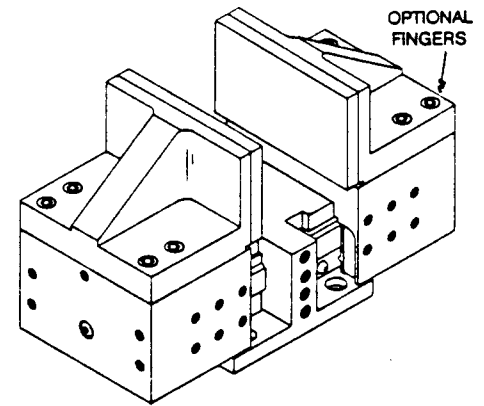
NOTE: *RAM HAS STANDARD .375 TRAVEL. SMALLER INCREMENTS ARE AVAILABLE UPON REQUEST. RETRACTED PUSHER WILL BE .125 BELOW THE FINGER MOUNTING SURFACE. CENTER VACUUM OPTION AVAILABLE.

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FLAT-PG-184



FLAT LINEAR ACTUATOR TRUE PARALLEL GRIPPER – FLAT-PG

DESCRIPTION:

The fingers' true parallel motion maximizes the payload capacity of your automated process by minimizing the distance between the robot's mounting flange and the top of the fingertips.

FEATURES:

- extremely low profile
- grips different sized parts with one programming height
- shielded bearings provide rapid linear gripping operation
- extensive finger travel range
- fingertip inserts may be mounted either on or behind permanent fingers
- easy fingertip insert installation
- replaceable fingertip inserts may be machined to fit a variety of parts and components
- fingers accept a wide range of sensing options
- smooth, low breakaway motion
- integral linear actuators
- hard coated, high strength 6061-T6 aluminum withstands harsh environments
- optional single-finger action
- works with Quick Change systems

APPLICATION:

Commonly used in pick and place operations, palletizing or depalletizing, assembly, and machine loading or unloading.

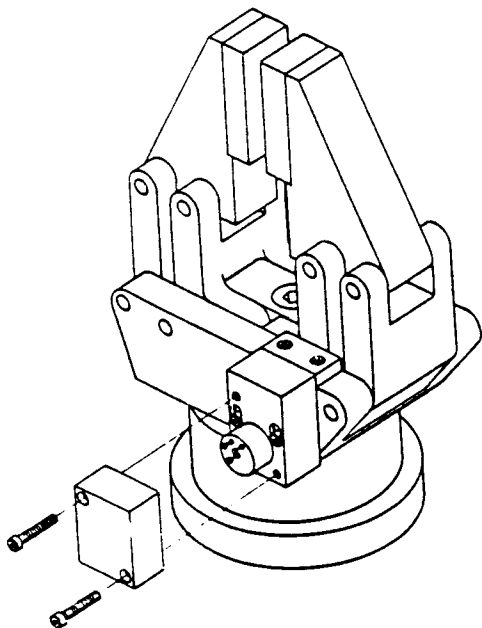
SIZES:

MODEL NO.	GRIPPING FORCE		TOTAL TRAVEL	A Width	B Length Closed	C Length Open	D Depth	E Mounting Bolt 4 Hole Pattern	F Bolt Hole
	80 PSI	100 PSI							
Flat-PG-184	IN 20.6	IN 25.8	1.0	1.875	3.625	4.625	1.562	#8 1.375 x 1.000	#8-32 x .375
	OUT 24.6	OUT 30.7							
Flat-PG-284	IN 29.2	IN 36.5	1.5	2.250	4.250	5.750	2.125	#10 1.250 x 1.750	#10-24 x .375
	OUT 35.4	OUT 44.2							

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(In Minnesota call: 612-633-5210)



SPG-EEP-484

SERVO-PNEUMATIC GRIPPER – SPG

DESCRIPTION:

This programmable Servo Pneumatic Gripping System has the capacity for an essentially infinite number of different positions, 1-second positioning time, and .02" repeatability. Fingers can be positioned at any position within the entire finger opening range.

FEATURES:

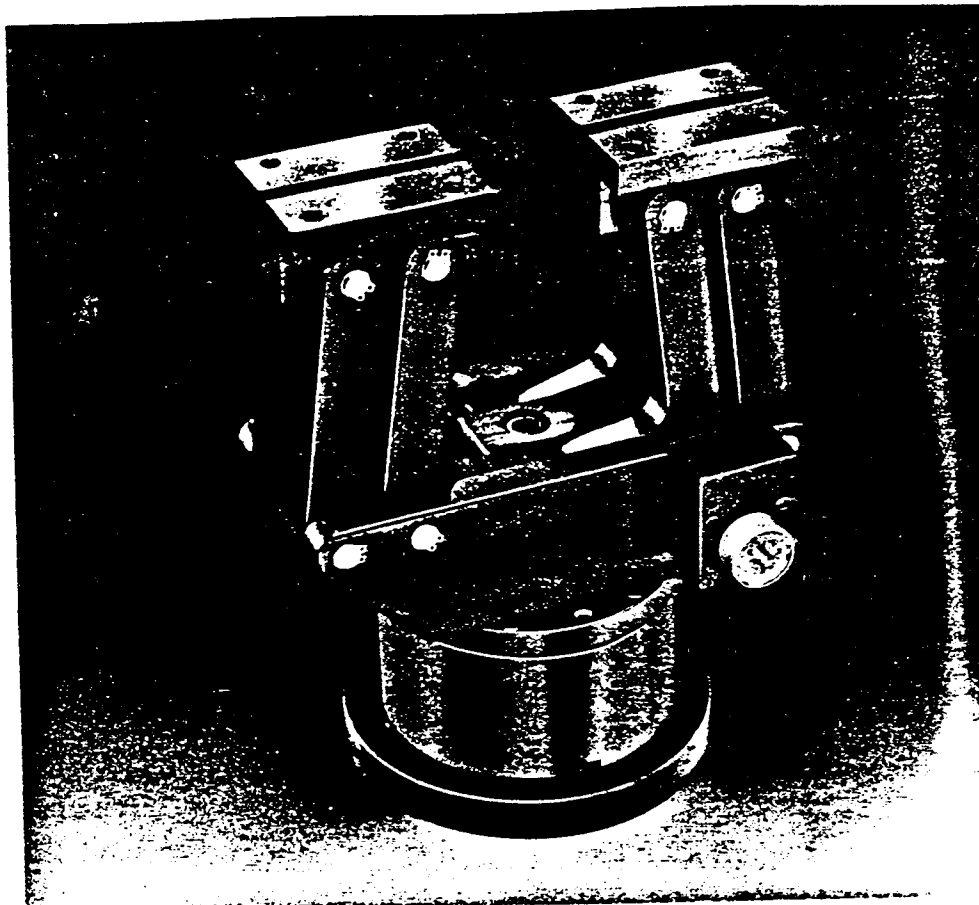
- controller has built-in analog interface (-10v DC to 10v DC)
- interfaces directly to robots or computers with analog interfaces
- RS-232/422 interfaces optionally available
- fingertips may have optional infrared sensors for parts sensing
- sensor outputs are TTL compatible
- environmental operating temperature range of 0°F to 120°F
- replaceable fingertip inserts may be machined to fit a variety of parts and components
- optional thru-body wiring
- smooth, low breakaway motion
- integral linear actuators
- hard coated, high strength 6061-T6 aluminum withstands harsh environments
- works with Quick Change systems

APPLICATION:

To allow efficient operation in applications requiring the manipulation of differently sized parts; enables the finger position of the Servo-Pneumatic Gripper (SPG) to be electronically controlled. The gripper controls can be interfaced with a robot controller or external computer to allow real time control of finger position.

SIZES:

See EEP-2-184, 284, 384, 484, 584 (pages 6-7) and EEPA-2 and EEPA-3-184, 284, 384 (pages 8-9) for gripper characteristics



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How to make sure your robot does a full day's work.

An introduction to Mecanotron Quick Change Systems.

The idea of making an investment in robotics is, in a very basic way, no different than hundreds of other decisions about capital purchases made by businesses like yours. If you can show that the expense will more than pay for itself, either by reducing operating expenses or increasing productivity, it's worth it.

Once the decision to invest in robotic systems is made, the next concern has to be getting the largest possible return out of that investment. And for a lot of businesses, that has meant the use of quick change tool systems. Because increasing productivity does not always mean buying more robots. It may mean getting more out of the robots you already have.

A lot of robots are smarter than they look.

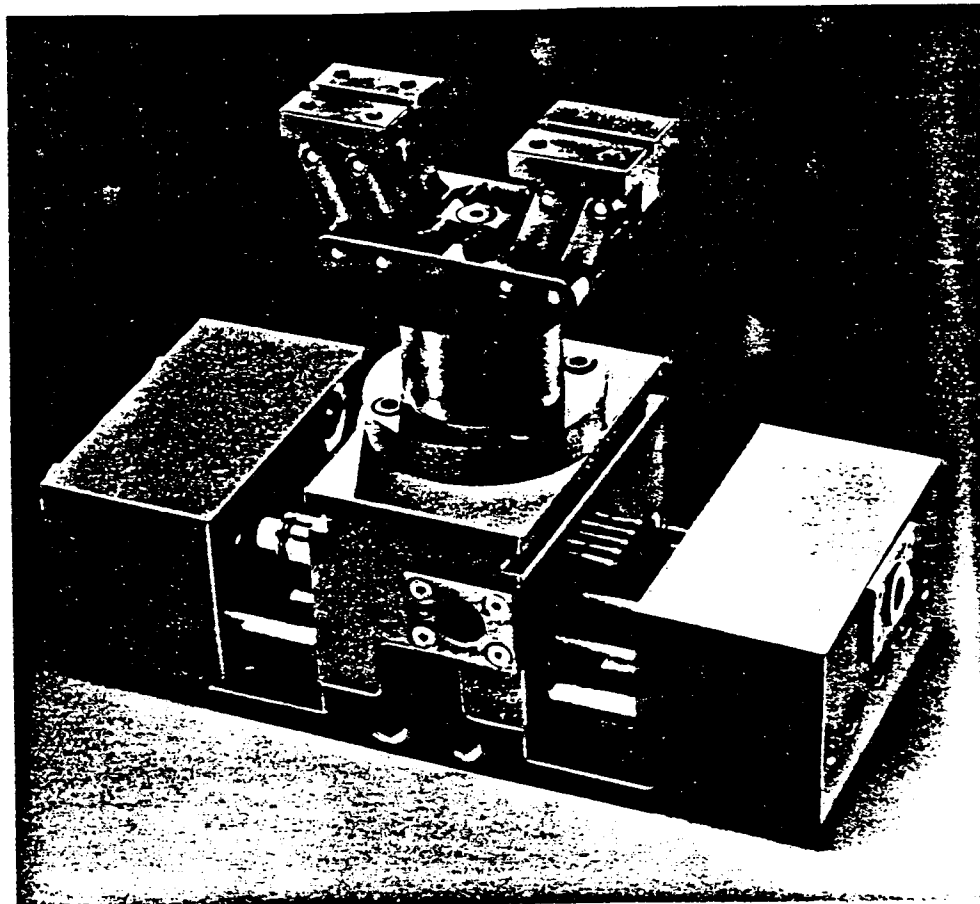
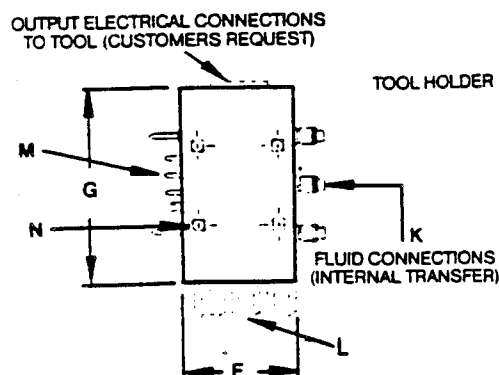
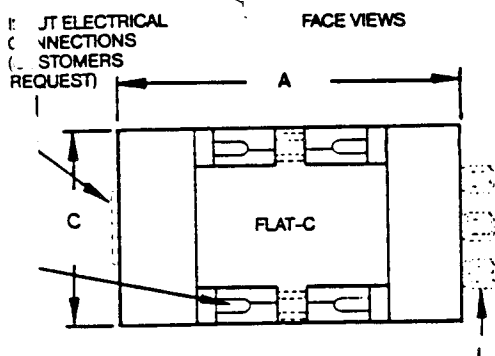
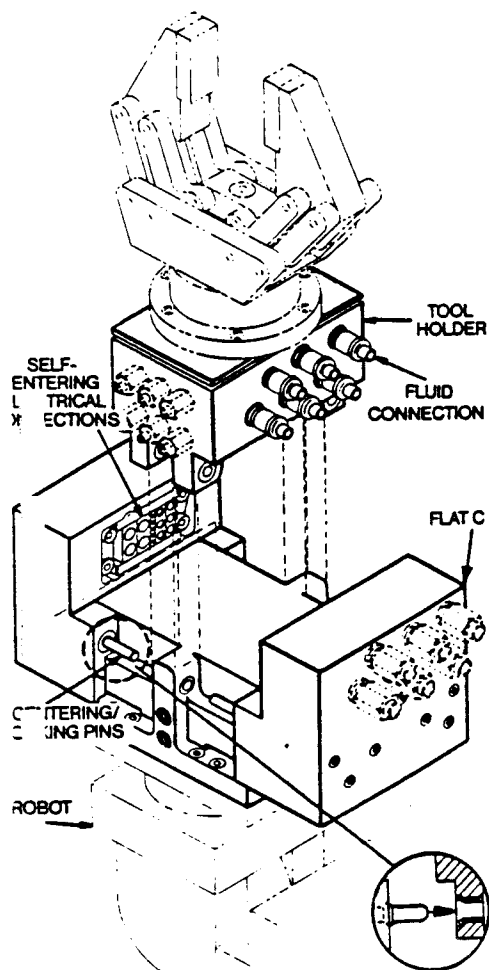
The common perception is that most robots are only capable of doing one thing over and over and over again. But in reality, most robots are capable of being far more industrious and flexible. All you have to do is give them a chance by providing them

with a system for changing tools between jobs.

Mecanotron quick change tool systems let you take full advantage of your robot's inherent flexibility without having to sacrifice either precision positioning, repeatability or reliability. So before you design your parts or process to accommodate your robot's capabilities, make sure you give your robot all of the tools it needs to be as productive as possible.

Increasing flexibility is one sure way to decrease downtime.

Some production processes move so swiftly, and are so complex, that the robots on the line never have a moments rest. But that is the exception. More often than not, robots "stand by" while they wait for their next opportunity. In both continuous and batch processes, quick change tool systems may allow you to put this spare time to more productive purposes. And a quick change system will also help you minimize any downtime that results from individual tool failure.



FLAT-C-184 WITH EEP-2-184

FLAT LINEAR ACTUATOR TOOL CHANGE SYSTEM – FLAT-C

DESCRIPTION:

When a system tool holder is seated against the Flat-C changer body and its "jaws" close, four stainless steel pins pass through hardened steel bushings in the holder to center it and lock it in place with .004" to .005" repeatability.

FEATURES:

- internal springs keep jaws closed and tool in place in case of operating pressure loss
- leak-free fluid transfer connections eliminate need for external valves during hold or release cycles
- "floating" electrical connectors align and protect gold-plated pins during tool exchange
- electrical and fluid service on opposing jaws reduces possibility of contamination
- all electrical and fluid connections are protected within the body
- lightweight, compact design
- high load capacity to weight ratio
- actuates in 1 second or less
- over 200 possible electrical configurations
- up to 200 Amp. connections available
- extremely impact resistant
- minimal maintenance required
- mounts easily and quickly to automated equipment
- wide range of sensing options
- thru-body wiring can accommodate coaxial, triaxial and fiber optic service when specified
- hard coated, high strength 6061-T6 aluminum withstands harsh environments

APPLICATION:

Commonly used where high payloads, rugged design and complex electrical/fluid configurations are required.

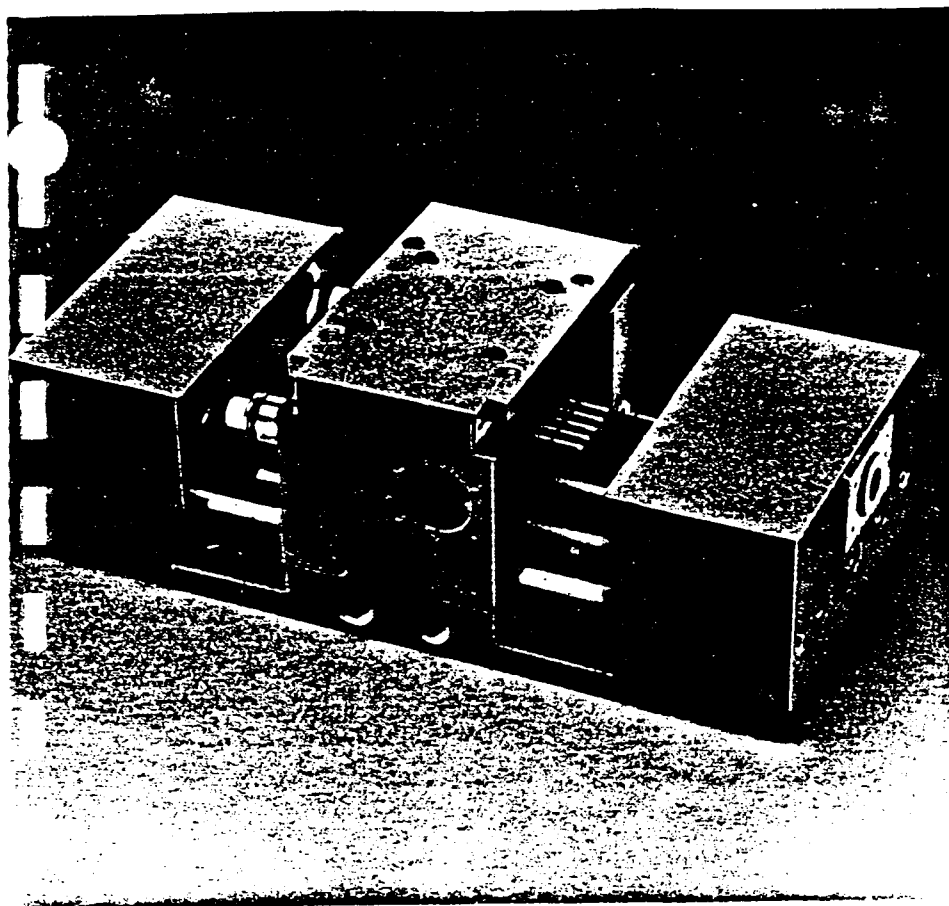
SIZES:

MODEL NO.	A	B	C	D	E	F	G	H	I	J
FLAT-C-184	7.800	5.800	3.100	2.100	2.050	2.000	3.100	2.600	3/16"	3.100x4.200
FLAT-C-284	7.850	5.850	4.250	3.400	2.750	2.500	4.250	3.900	1/4"	4.250x4.300
FLAT-C-384	9.000	7.000	5.250	5.000	3.250	3.000	5.250	5.750	3/8"	5.250x4.250

CALL 1-800-544-9266

(In Minnesota call: 612-633-5210)

CALL 1-800-544-9266 for Standard, Modified or Custom End Effectors.

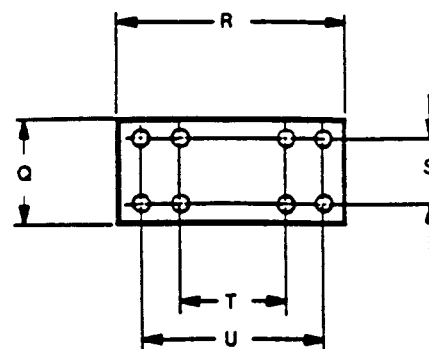


FLAT-C-184

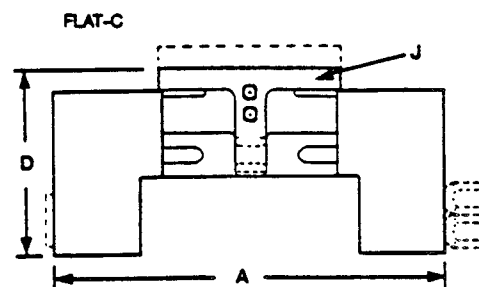
MODEL NO.	K	L	M	N	O	P LBS.	FLOW DIA.
FLAT-C-184	2	(2)1/8 NPT	(5)8 amp	1.719	100/20	2.50/.50	7/32
FLAT-C-284	2	(2)1/8 NPT	(10)8 amp/(3)15 amp	2.312	300/60	4.06/1.56	7/32
FLAT-C-384	4	(4)1/8 NPT	(10)8 amp/(4)25 amp	3.500	800/150	9.50/3.00	7/32

MOUNTING BOLT HOLE PATTERN

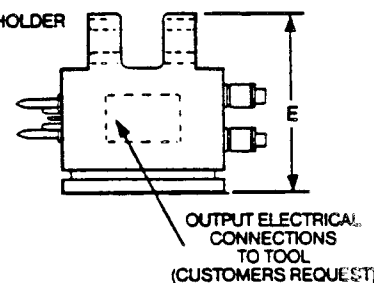
MODEL NO.	Q	R	S	T	U
FLAT-C-184	3.100	4.200	2.600	2.500	3.500
FLAT-C-284	4.250	4.300	3.700	2.250	3.600
FLAT-C-384	5.250	4.250	4.700	2.250	3.600



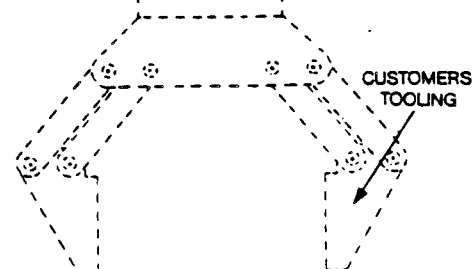
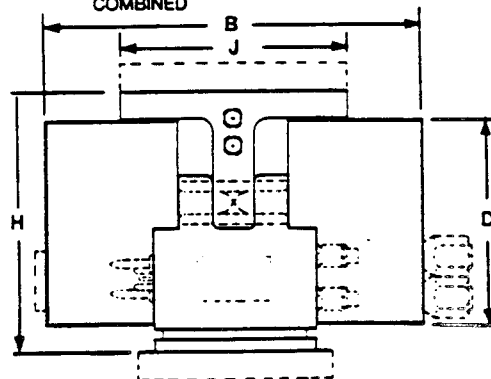
SIDE VIEWS



TOOL HOLDER



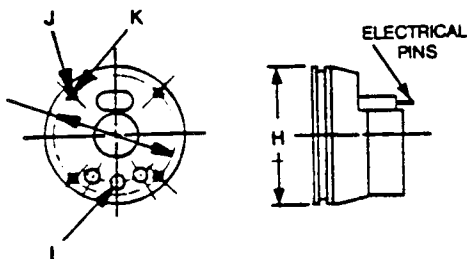
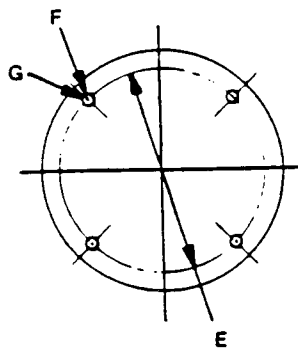
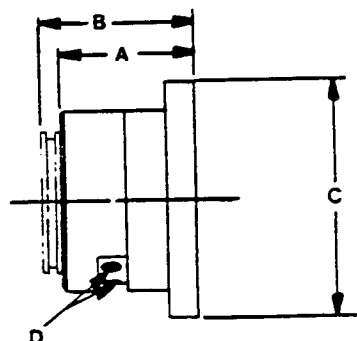
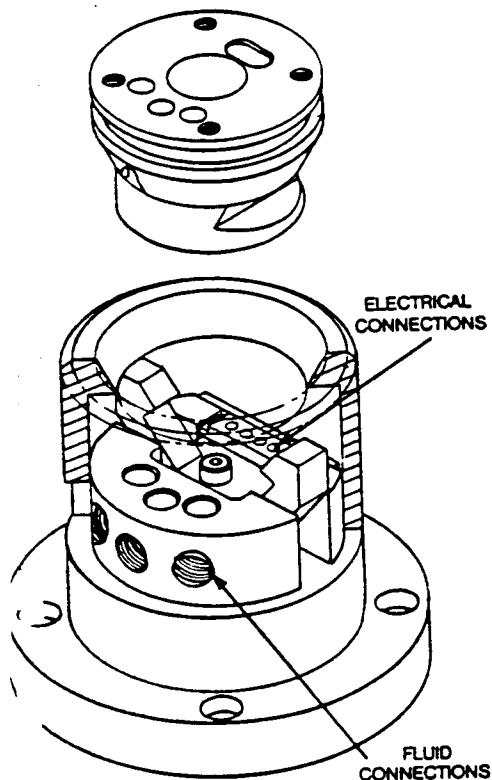
FLAT-C AND TOOL HOLDER COMBINED



CALL 1-800-544-9266 for Standard, Modified or Custom End Effectors.

CALL 1-800-544-9266

(In Minnesota call: 612-633-5210)



URW-184

UNIVERSAL ROBOT WRIST - URW

DESCRIPTION:

The unique, taper design provides an exceptionally tight fit and repeatability between the wrist and the tool holder. An internal cylinder operates two gripping fingers in the wrist which precisely position and seat the tool holder in the connection cavity. A guide pin in the wrist assures proper alignment of the tool holder.

FEATURES:

- repeatability of $\pm .002''$
- narrow profile for extremely close tolerance environments
- unique taper design significantly decreases loss of accuracy due to wear
- internal locking device secures tool holder in case of pressure loss
- thru-body electrical/fluid connections reduce possibility of damage due to environmental conditions
- long-life, low friction, gold-plated electrical pins minimize maintenance
- broad selection of electrical connector capabilities
- accommodates electrical, motorized devices
- mounts easily and quickly to automated equipment
- wide range of sensing options
- reliable, cost-effective design
- hard coated, high strength 6061-T6 aluminum withstands harsh environments

APPLICATION:

Commonly used in environments where a high degree of repeatability is required and a small work envelope restricts tool movement.

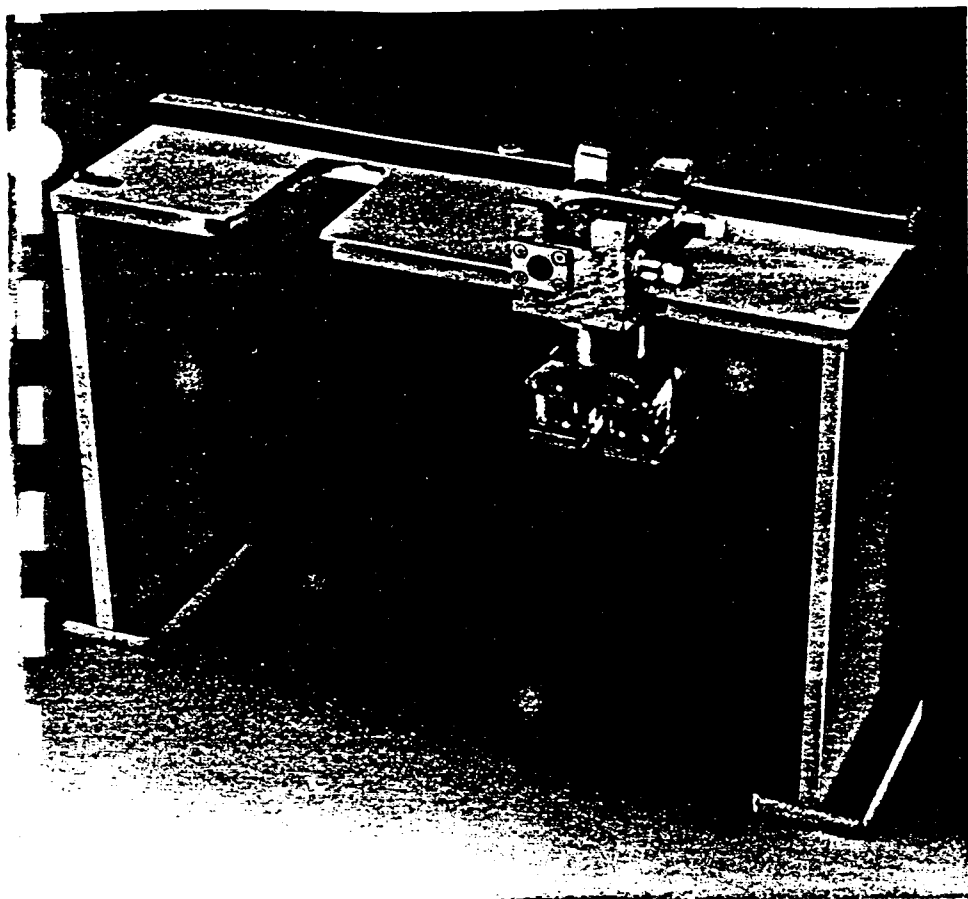
SIZES:

MODEL NO.	Approx. Overall Weight		Lifting Capacity Dynamic Loading @ 2 G's									
URW-184	1.9 #		28# / 5 ft. lbs.									
URW-284	2.9 #		89# / 20 ft. lbs.									
URW-384	5.8 #		272# / 62 ft. lbs.									
MODEL NO.	WRIST							TOOL HOLDER				
	A	B	C	D	E	F	G	H DIA.	I DIA.	J	K	L DIA.
URW-184	2.812	3.125	3.500	1/8 NPT	3.062	10 SHCS (4)	2.062	3@.187	4	8-32 x .375	1.719	
URW-284	3.000	3.290	4.500	1/8 NPT	4.000	1/4 SHCS (6)	2.750	3@.250	4	10-24 x .375	2.312	
URW-384	3.187	3.625	6.000	1/4 NPT	5.500	1/4 SHCS (6)	4.125	4@.250	6	10-32 x .375	3.500	

CALL 1-800-544-9266

(In Minnesota call: 612-633-5210)

CALL 1-800-544-9266 for Standard, Modified or Custom End Effectors.



THR-F-184 CUSTOM TWO POSITION

RIGID TOOL HOLDER RACK (STANDARD)-THR

DESCRIPTION:

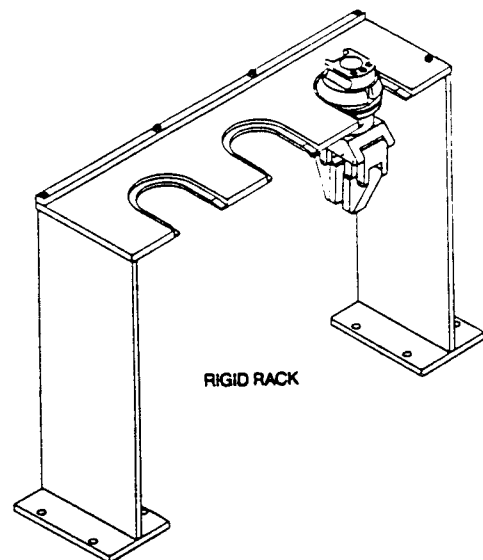
These rigid aluminum racks provide tool changers with easy access to tool holders. They contain three bays which secure the tool holder/end effector units when they are not in use. URW Racks utilize alignment pins to keep tool holders in place.

FEATURES:

- optional shock-resistant, compliant bays
- multiple bays available on a custom basis
- sensors may be installed to indicate tool availability or use

APPLICATION:

Commonly used in any work cell where Mecanotron Flat-C or Universal Robot Wrist Quick Change Systems are in operation.

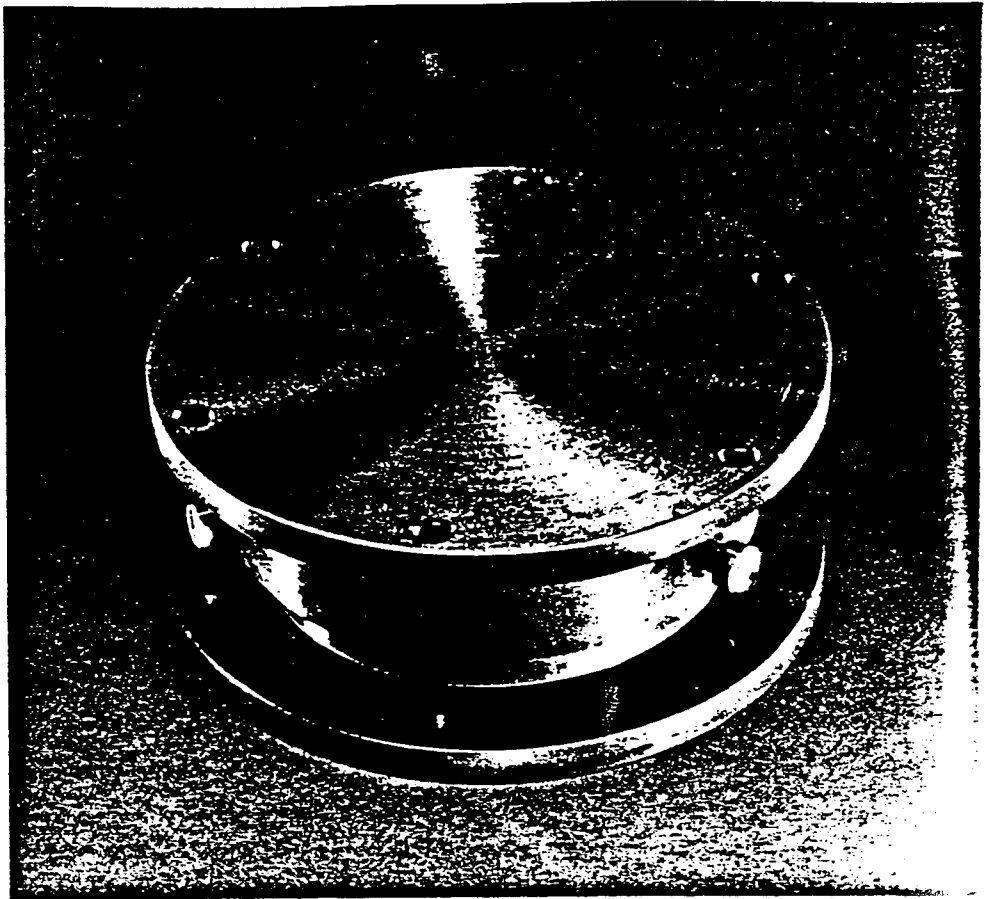
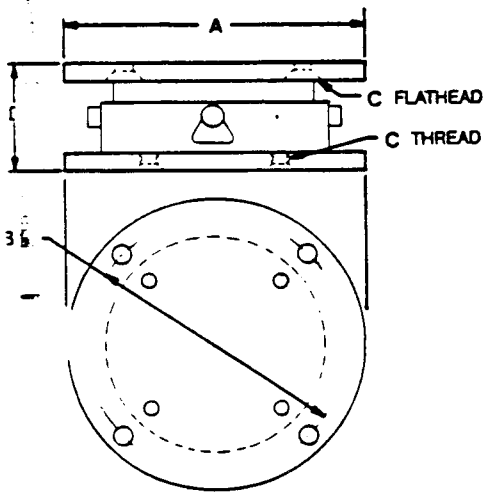
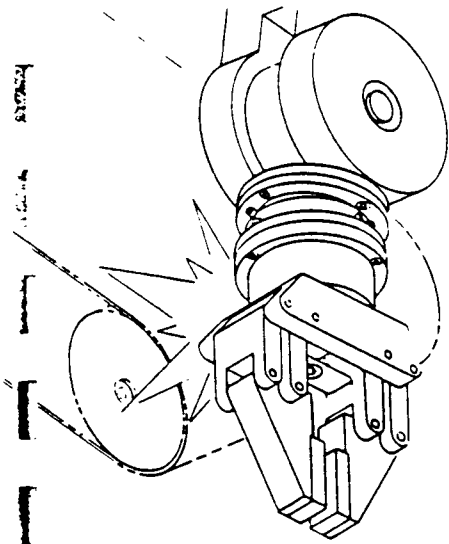


RIGID RACK

CALL 1-800-544-9266 for Standard, Modified or Custom End Effectors.

CALL 1-800-544-9266

(In Minnesota call: 612-633-5210)



OPW-484

OVERLOAD PROTECTOR WRIST – OPW

DESCRIPTION:

The OPW is designed to replace expendable breakaway joints that generate downtime, damage and cost. Mounted between the end effector and the robot mounting flange, the OPW deflects and cushions shocks caused by the end effector unexpectedly colliding with another object. When the OPW detects increasing load on the end effector, it generates an electrical signal that is used to shut off robot motor power. The OPW also provides angular compliance to protect the end effector while the robot is stopping. This combined action provides an high level of protection against collision damage.

FEATURES:

- response time of .5 milliseconds
- automatic reset minimizes downtime
- commands robot to shut down, return to home, or perform other pre-determined tasks
- allows for torsional, angular and linear compliance
- requires no replacement parts or reprogramming

APPLICATION:

The overload protector wrist (OPW) is mounted between the robot mounting flange and the end effector to detect excessive loading on the end effector. It is especially useful in situations where misplaced or defective work pieces may cause collisions resulting in damage to the robot, tooling or work. It is also useful for detecting wire stick in welding applications or obstructions on sealing or epoxy applications.

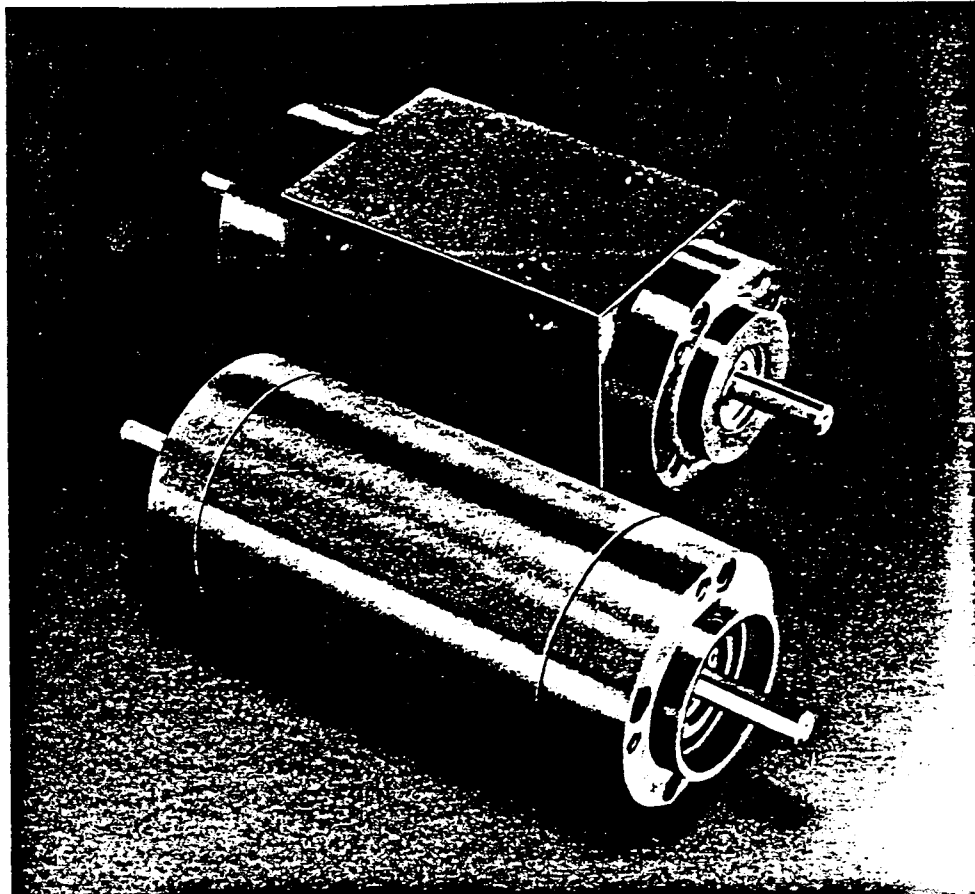
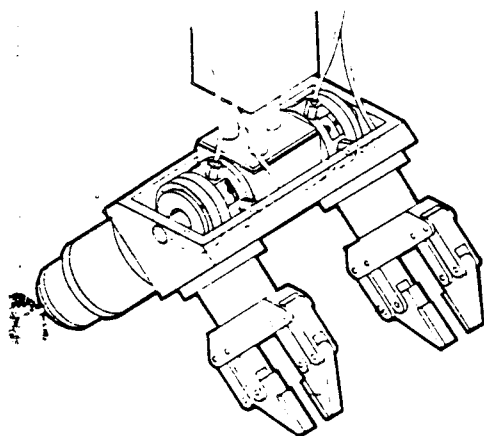
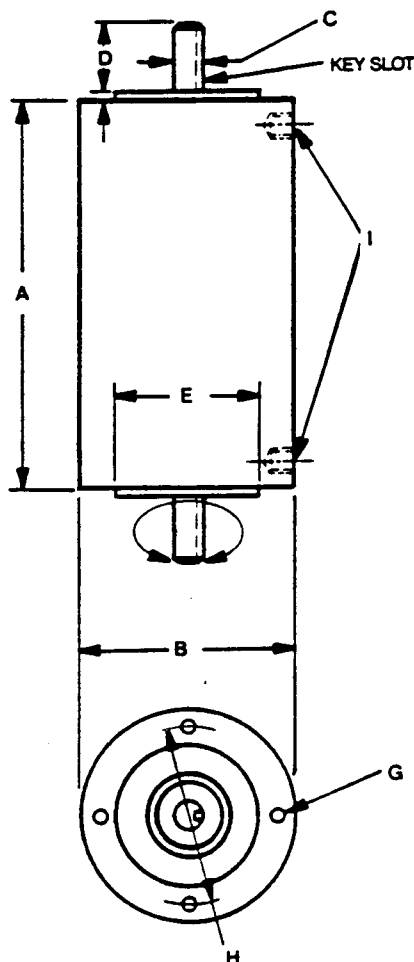
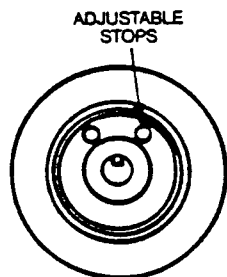
SIZES:

MODEL NO.	A OUTSIDE DIA.	B BOLT CIRCLE	C BOLT SIZE	D HEIGHT	E WEIGHT
OPW-184	2.062	1.718	#6-32	1.218	4 oz.
OPW-284	2.750	2.312	#10-24	1.500	12 oz.
OPW-384	4.000	3.500	#10-24	1.750	15 oz.
OPW-484	5.000	4.500	¼-20	2.125	24 oz.

CALL 1-800-544-9266

(In Minnesota call: 612-633-5210)

CALL 1-800-544-9266 for Standard, Modified or Custom End Effectors.



RA-184; RA-184 SQUARE BODY

ROTARY ACTUATOR – RA

DESCRIPTION:

Lightweight, powerful and compact with outstanding strength and repeatability. Provides a full 360° rotation with the capability for adjustable hard stops (184 size only) for accurate positioning.

FEATURES:

- 360° of standard rotation
- multiple hard stops with infinitely adjustable positioning plate (184)
- lightweight, low-profile design maximizes payload
- sealed, zero-leakage construction
- smooth, low breakaway motion
- keyway slotted rotary shaft allows device attachment at either or both ends
- optional stainless steel or square body models
- up to 900° rotation available on custom basis
- clean room compatible
- hard coated, high strength 6061-T6 aluminum withstands harsh environments

APPLICATION:

Commonly used in conjunction with a clevis assembly to position grippers, adds an additional rotational axis to a robot, acts as a rotational positioning device for hard automation systems.

Also available: 3-rod Linear Actuators. Call for specs.

SIZES:

MODEL NO.	Dimensions								
	A	B	C	D	E	F	G	H	I
RA-184	4.438	2.000	.250	.750	1.375	.250	10-24	1.688	10-32
RA-584	5.125	7.000	.750	1.000	3.000	.375	1/4-24	4.000	1/2-NPT

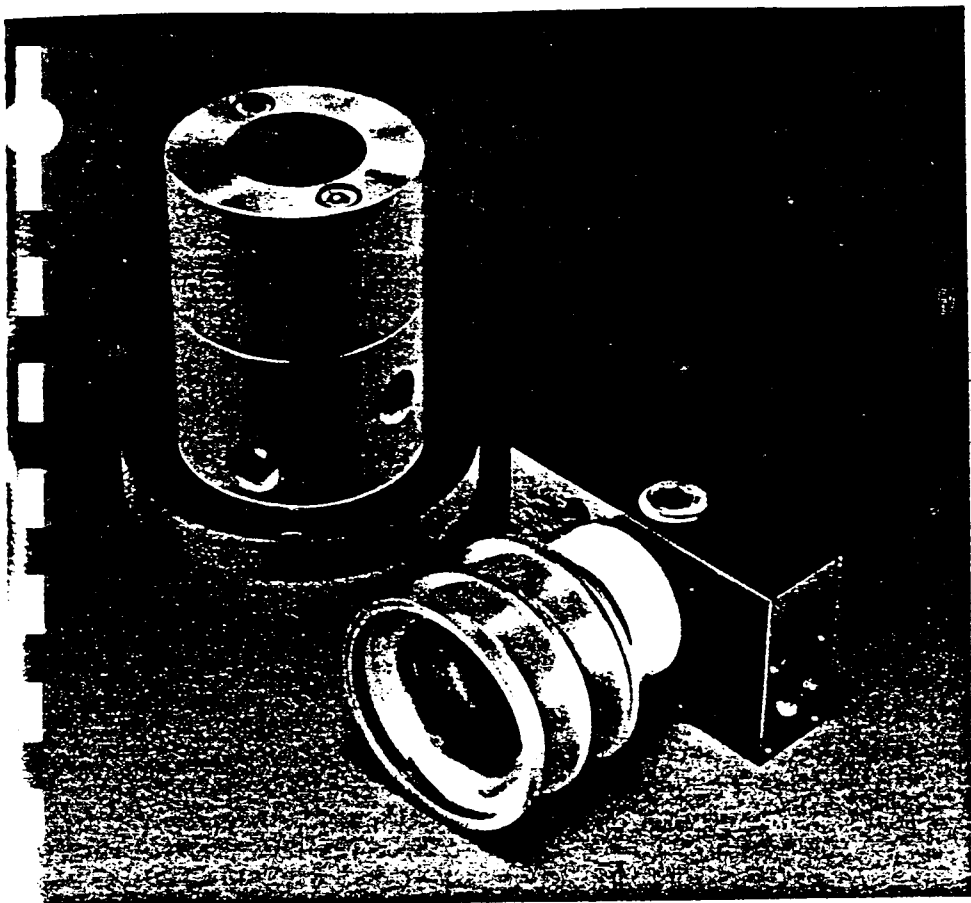
MODEL NO.	Torque in Inch Lbs. @ 80 psi	Keyway Size	Weight
RA-184	5	Width: .093 Depth: .093	1.5 LBS
RA-584	160	Width: .250 Depth: 1.250	17 LBS

Additional sizes available

CALL 1-800-544-9266

(In Minnesota call: 612-633-5210)

CALL 1-800-544-9266 for Standard, Modified or Custom End Effectors.



VACUUM GENERATORS AND MAGNETS

VACUUM GENERATORS AND MAGNETS

DESCRIPTION:

A wide variety of venturi vacuum, electro magnet and permanent magnet grippers and gripping systems are available as standard products.

APPLICATION:

Commonly used in pick and place operations, palletizing or depalletizing and machine loading or unloading.

SENSORS

DESCRIPTION:

The use of sensors enables industrial robots to perform an increasing number of useful tasks by allowing feedback from the robot's environment. Mecanotron can integrate a wide variety of sensors with end effector systems. Sensors are available for position, force, heat and many other factors that can affect a robot's work.

FEATURES:

- can be designed to work with virtually any end effector or robot
- designs available for systems requiring digital or analog interfacing
- customized for specific applications

APPLICATION:

Sensors are commonly interfaced with robots to monitor their travel, display position or velocity or to react to unusual conditions. Ideal for use with robots to monitor and react to peripheral processes such as material handling, machine load/unload, conveyors, assembly, inspection, etc.

CALL 1-800-544-9266 for Standard, Modified or Custom End Effectors.

Additional Products

Mecanotron can also provide top-quality modified or customized vacuum generators, magnets, custom grippers, interface plates, custom fingers, and 3-rod linear actuators to meet your specific needs. Our R&D engineers are continually developing new products to meet the constantly changing demands of the rapidly growing robotics industry.

If you don't see the product or products you need in this brochure, please give us a call. The product you're looking for just might be on the drawing board or already working for one of our customers. If not, we'll be happy to modify, customize or design a product to meet your exact specifications.

NOTE: All specifications subject to change without notice

CALL 1-800-544-9266

(In Minnesota call: 612-633-5210)

Customer Support Services.

When you do business with Mecanotron, you can be sure that you are dealing with professionals who are truly committed to you and your success. Our business has been built on our ability to successfully solve end effector problems for our customers. But our responsibility to our customers doesn't end there.

A warranty that's second to none.

We are proud to back our products with the strongest warranty in the end effector industry. And, while the actual life of an end effector depends on how it is used, we at Mecanotron can confidently say that our end effectors will perform as promised or we will repair or replace them. Period.

In most cases, we are able to guarantee that our end effectors will perform satisfactorily under normal use as specified for a period of 120 days from *system installation*. In some cases, the anticipated use of the end effector will make it necessary for us to modify that warranty. Under those circumstances, we will discuss

your needs with you and agree on a special modified warranty at the time you place your order.

No one in the industry offers a stronger warranty. No one dares.

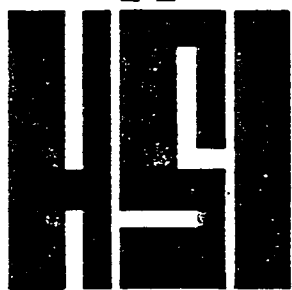
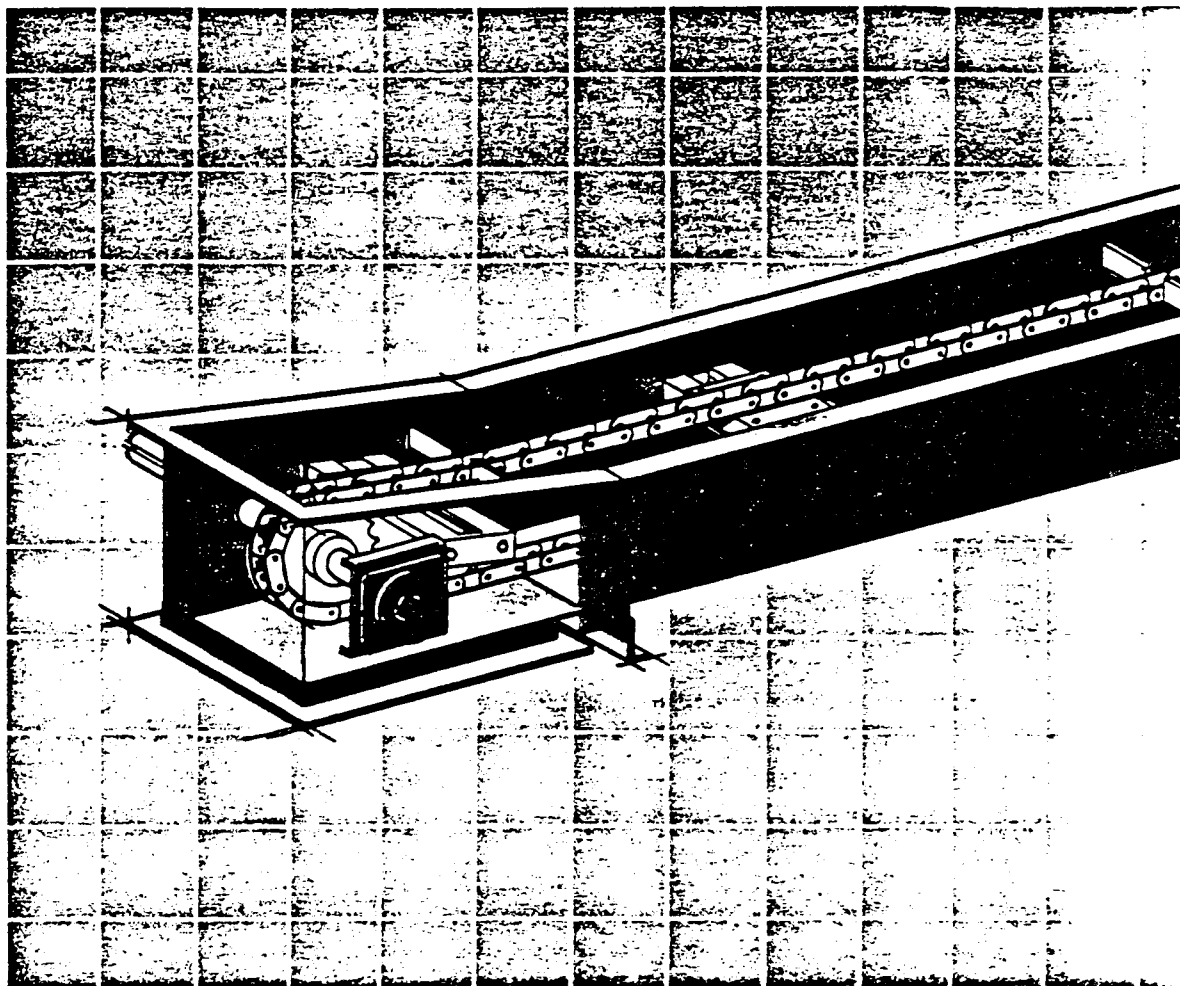
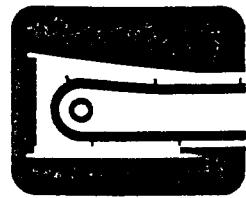
Help when you need it.

Whenever you use a Mecanotron product, you can be sure that Mecanotron is standing solidly behind it...100 percent. We're never more than a phone call away to answer questions or advise you on solutions to problems whenever and wherever they occur. As your needs change, our people are available to discuss cost effective ways to maximize your end effector and robotic investments. We're here to help your robotic system succeed. Our future depends on it.

Mecanotron...a company you can depend on.

We have the people, the products and the proven experience to help you find solutions to your end effector problems. If you have any questions, please give us a call.

TYPE E EN-MASSE CONVEYORS



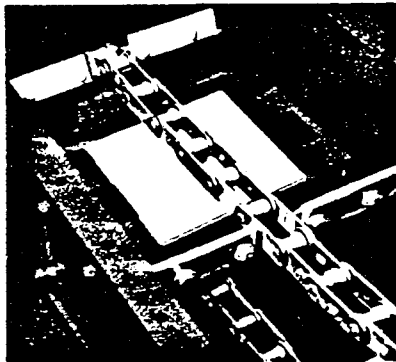
HUSS & SCHLIEPER, INC.

Manufacturers - Designers - Grain Handling Systems & Machinery

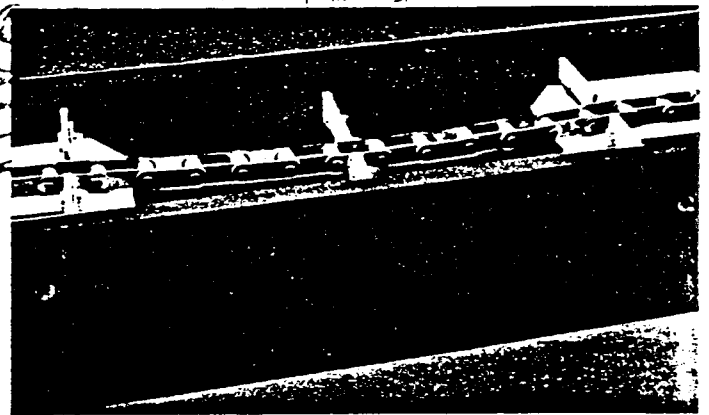
Someone finally put Huss & Schlieper quality in an economical, low volume conveyor

We designed the Type E Conveyor to provide a *mass flow alternative to a U Trough Conveyor*, to provide for lower capacities in a noncontinuous service application and at the same time combine economy with *quality*. Mass flow features include low vibration, low noise levels, longer life, less product degradation, less carryover, compact size, plus H.S.I. engineering and craftsmanship throughout.

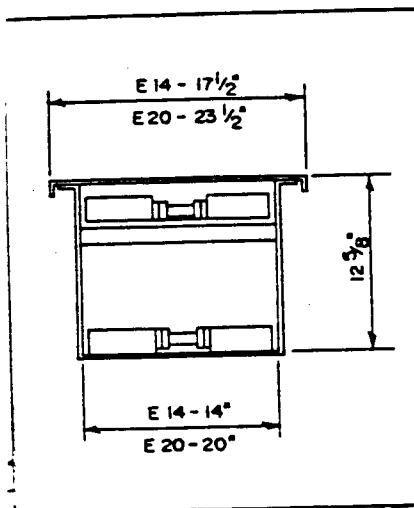
The Type E features En-Masse operation for greater efficiency, less maintenance—smoother operation.



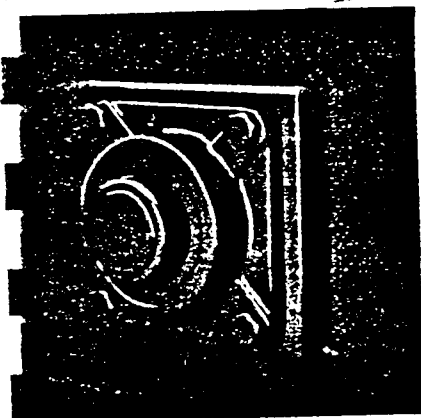
The UHMW-lined return and flights minimize chain wear and decreases noise.



Spaced chain return plates increase cantenary action to help maintain chain tension.



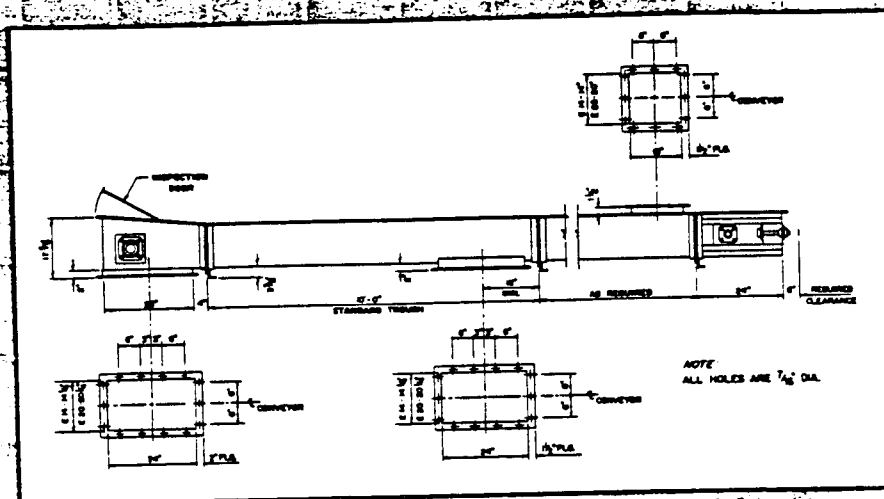
The type E Conveyor fits into compact space—much lower than U Trough counterpart.



Vented bearings promote long safe life and easy maintenance

TYPE E SPECIFICATIONS

14" & 20" Type E En-masse Conveyor



CAPACITY CHART

SPEED FPM		1	50	75	100	125	150	175	200	225
CAPACITY E14 SERIES	CU. FT./HR.	45	2250	3375	4500	5625	6750	7875	9000	
	BU./HR.	36	1800	2700	3600	4500	5400	6300	7200	
CAPACITY E20 SERIES	CU. FT./HR.	67	3350	5025	6700	8375	10,050	11,725	13,400	15,075
	BU./HR.	54	2700	4050	5400	6750	8100	9450	10,800	12,150

Both series incline to 15°

QUALITY ENGINEERING... TO FIT YOUR NEEDS

- By-Pass Inlets
- Bend sections
- Self Cleaning option
- Full line-discharge gates
- FM cleaning section

MANUFACTURERS OF

EN MASSE CONVEYORS

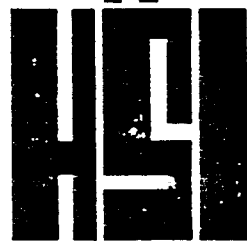
BUCKET ELEVATORS

SCREW CONVEYORS

GRAIN DISTRIBUTORS

BARGE/SHIP LOADERS

FITTINGS & FIXTURES

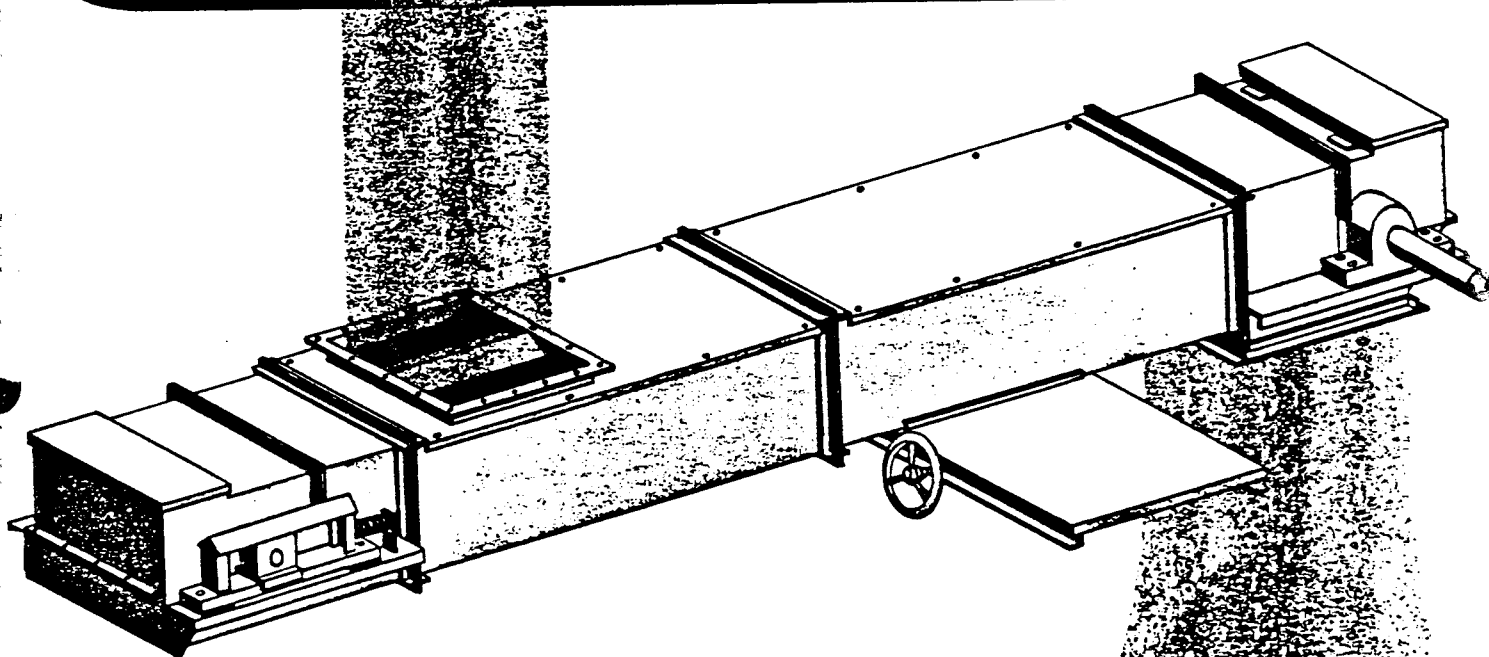


HUSS & SCHLIEPER, INC.

P.O. Box A511, Decatur, Illinois 62525 800/637-1567, Illinois 800/252-1579

Kleen Flo

DRAG CONVEYORS



A complete line of heavy-duty
en masse conveyors designed to
take care of the most severe
applications:

- Capacities ranging up to
95,000 B.P.H.
- Lengths up to 400 feet



HUSS & SCHLIEPER

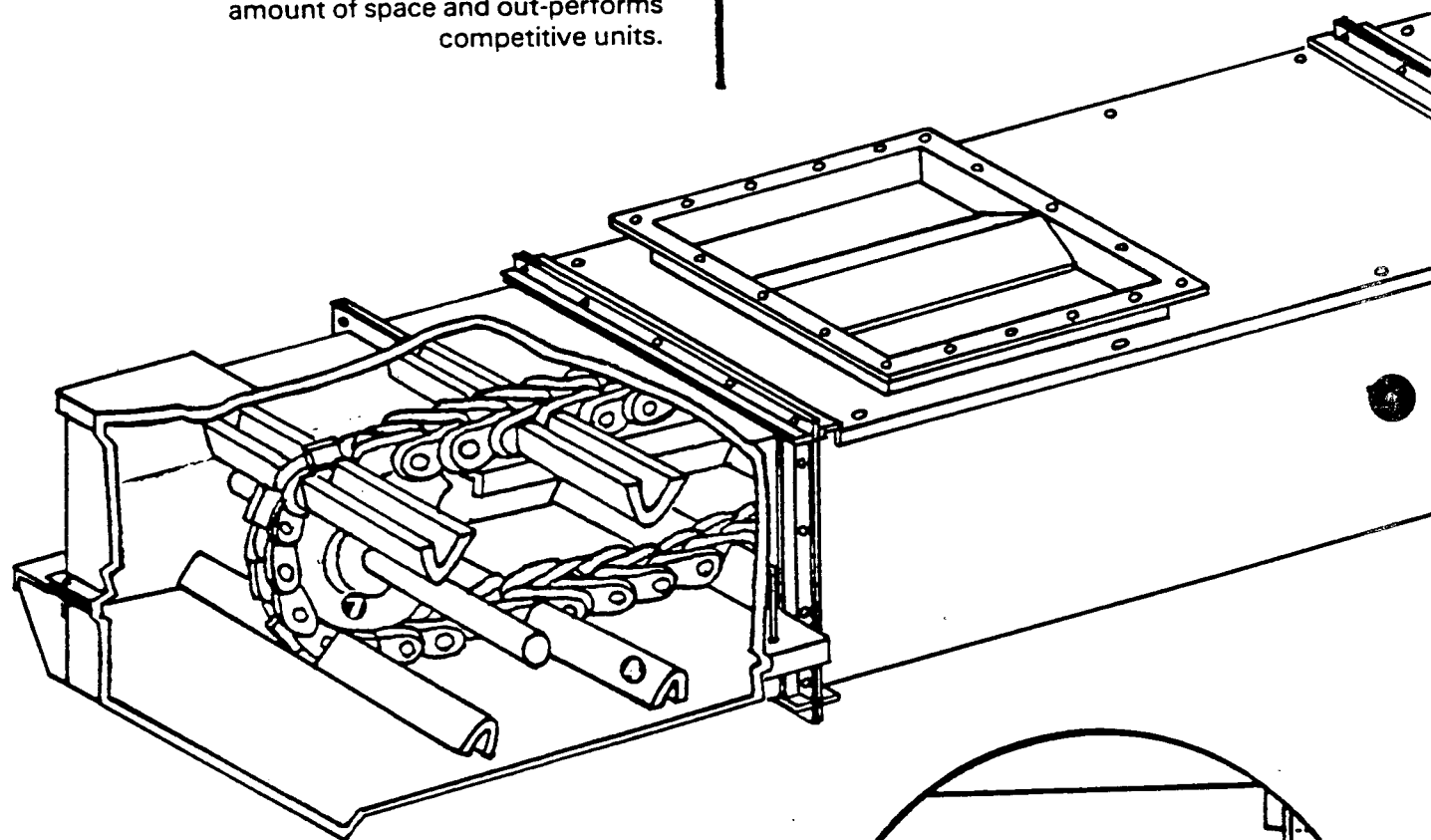
2230 BRUSH COLLEGE ROAD · P.O. BOX 949
DECATUR, IL 62525 · 217/423-6001

Huss & Schlieper method eliminates

Huss & Schlieper's newly designed drag conveyor features a U.H.M.W. polyethylene liner that not only affords increased life and less horse power, but eliminates the drawbacks of other U.H.M.W.-lined conveyors by compensating for the variation in expansion rates between the polyethylene liner and the steel housing. The Kleen-Flo en masse system also incorporates a new flight design that virtually eliminates the problem of carry-over at the intermediate discharge points: The result is a high volume, enclosed conveyor that requires a minimum amount of space and out-performs competitive units.

Check these convenient and

- ① Inspection hatch
- ② Completely removable hoods for easy removal of shaft and sprocket assembly
- ③ Self-aligning spherical roller bearings
- ④ Exclusive Huss & Schlieper cupped flights (patent pending)
- ⑤ Welded steel heavy duty conveyor chain



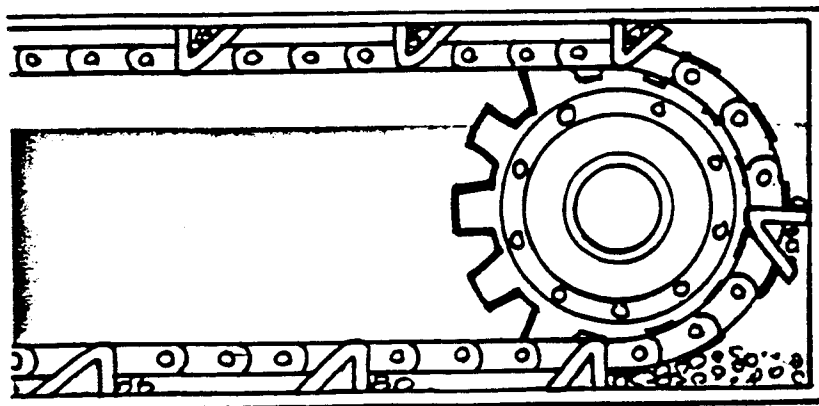
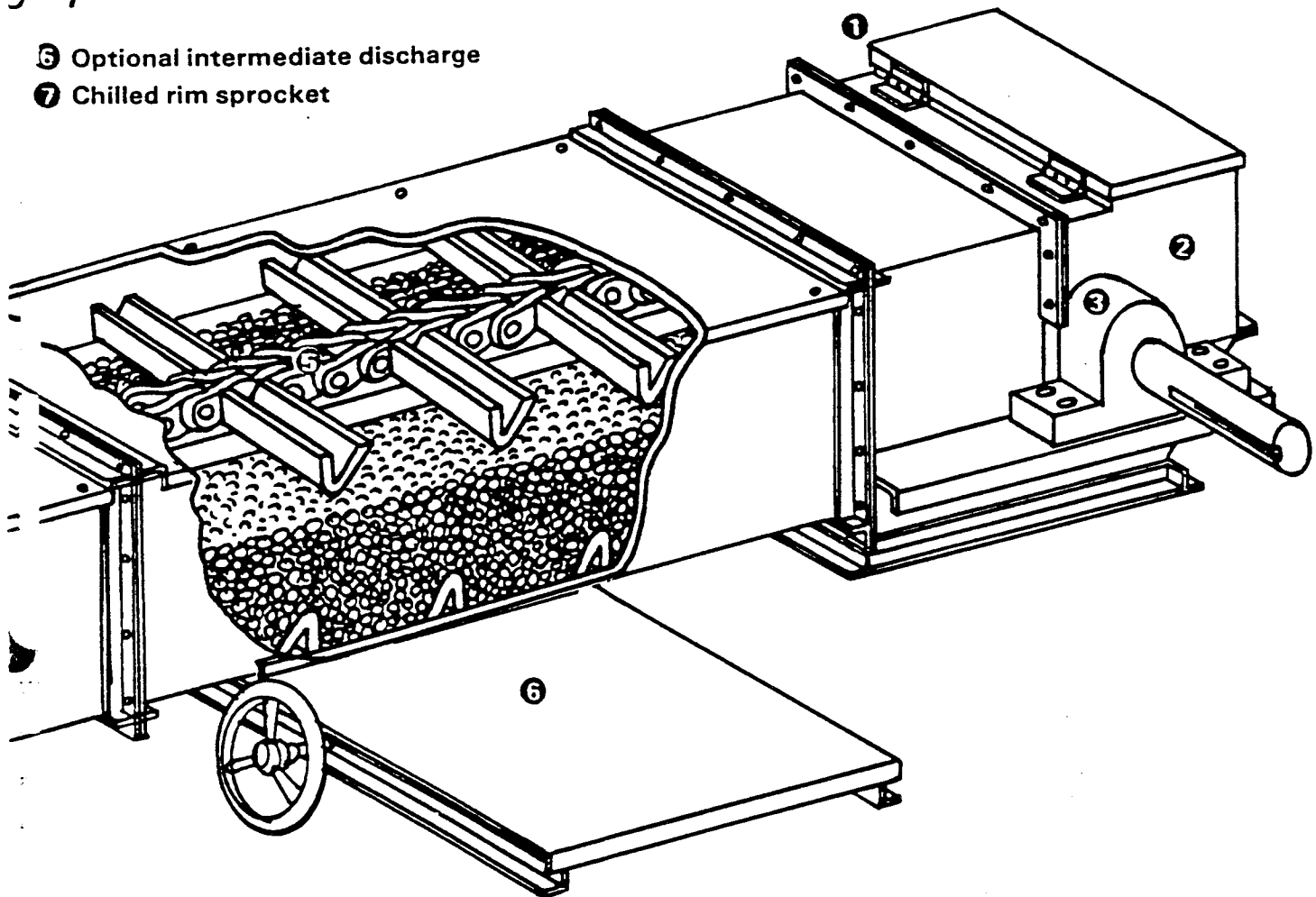
Replaceable U.H.M.W. Polyethylene Liner

The trough of this new Kleen-Flo Drag Conveyor is lined on the bottom and sides with 3/8" thick U.H.M.W. polyethylene. This tough liner outwears steel by approximately a 7 to 1 ratio, adding years to the life of the equipment. And, unlike the steel of unlined conveyors, it can be replaced when it finally does show wear. In addition, the new Huss & Schlieper design compensates for the variation in the expansion rates between the polyethylene liner and the steel housing to eliminate any possibility of buckling or wrinkling of the liner. The non-sparking liner is safer; it reduces friction which makes it possible to move more grain with less horsepower, and it reduces the operational noise levels considerably below ordinary drag conveyors.

Additional drag conveyor problems

High performance features:

- ⑥ Optional intermediate discharge
- ⑦ Chilled rim sprocket



Newly designed skeleton flight provides smooth starts under load with low power requirements. Huss & Schlieper's exclusive cup-shaped flights control the "carry-over" by catching material and recycling it.

CAPACITY CHART — UNITS PER HOUR

CONV. SIZE	UNITS	SPEED - FEET PER MINUTE										
		1	50	75	100	125	150	175	200	225	250	275
12x22	CU. FT.	68.4	3420	5130	6840	8550	10260	11970	13680	15390	17100	18810
	BU.	54.7	2730	4100	5470	6840	8200	9570	10940	12310	13680	15040
18x22	CU. FT.	106.3	5310	7970	10630	13280	15940	18600	21260	23910	26570	29230
	BU.	85.0	4250	6370	8500	10630	12750	14880	17000	19130	21260	23380
24x22	CU. FT.	144.2	7210	10810	14420	18020	21630	25230	28840	32440	36050	39650
	BU.	115.3	5760	8650	11530	14420	17300	20180	23070	25950	28840	31720
30x22	CU. FT.	182.1	9100	13650	18210	22760	27310	31860	36420	40970	45520	50070
	BU.	145.6	7280	10920	14560	18210	21850	25490	29130	32770	36420	40060
18x28	CU. FT.	136.9	6840	10260	13690	17110	20530	23950	27380	30800	34220	37640
	BU.	109.5	5470	8210	10950	13690	16420	19160	21900	24640	27380	30110
24x28	CU. FT.	186.7	9330	14000	18670	23330	28000	32670	37340	42000	46670	51340
	BU.	149.3	7460	11200	14930	18670	22400	26130	29870	33600	37340	41070
30x28	CU. FT.	234.3	11810	17720	23630	29530	35440	41350	47260	53160	59070	64980
	BU.	189.0	9450	14170	18900	23630	28350	33080	37800	42530	47260	51980
36x28	CU. FT.	286.0	14300	21450	28600	35750	42900	50050	57200	64350	71500	78650
	BU.	228.8	11440	17160	22880	28600	34320	40040	45760	51480	57200	62920
42x28	CU. FT.	335.7	16780	25170	33570	41960	50350	58740	67140	75530	83920	92310
	BU.	268.5	13420	20140	26850	33570	40280	46990	53710	60420	67140	73850
48x28	CU. FT.	385.4	19270	28900	38540	48170	57810	67440	77080	86710	96350	105980
	BU.	308.3	15410	23120	30830	38540	46240	53950	61660	69370	77080	84780
54x28	CU. FT.	435.1	21750	32630	43510	54380	65260	76140	87020	97890	108770	119650
	BU.	348.0	17400	26100	34800	43510	52210	60910	69610	78310	87020	95720

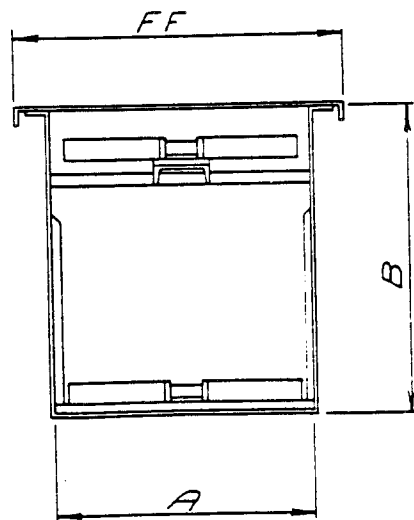
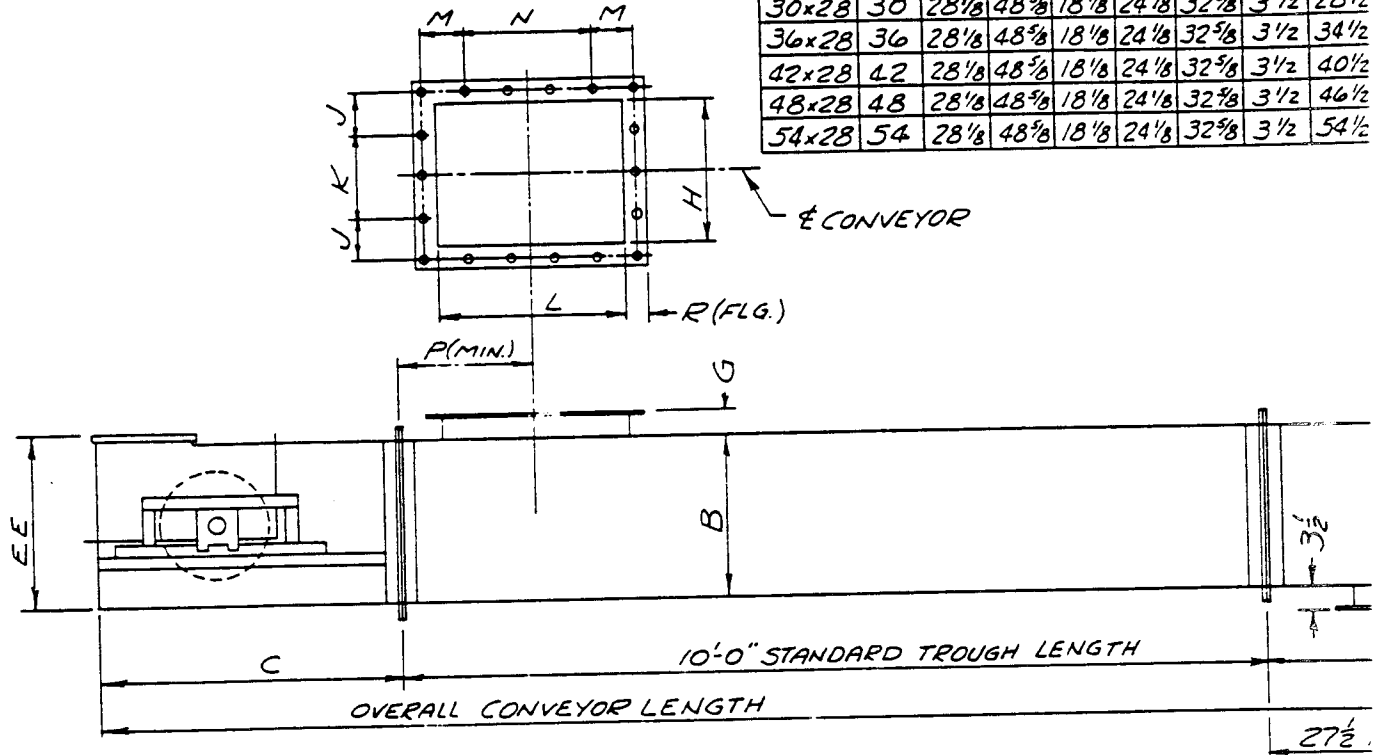
Kleen Flo[®]

HEAVY DUTY DRAG CONVEYOR ...FOR BETTER PERFORMANCE

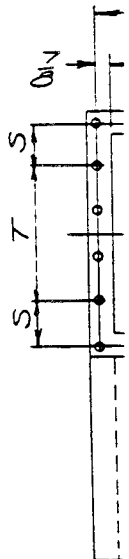
- Complete range of sizes up to 95,000 bu/hr.
- Honest-rated capacities.
- Conveyor lengths to 400 ft.
- Low profile inlet and outlet, requires minimum space.
- Totally enclosed — dust and weather tight — reducing air pollution, material contamination.
- Replaceable, U.H.M.W. polyethylene liner — outlasts abrasive resistant steel, quiet, non-sparking.
- Completely detachable covers for easy inspection of chain and material.
- Lower horsepower requirements than conventional drag conveyors.
- Self-aligning spherical roller bearings.
- Only 4 lubricating points for easy maintenance.
- Spring cushioned take-up reduces shock.
- Standard welded steel, heavy-duty conveyor chain.
- Hardened sprockets.
- Easy-to-automate multiple intermediate discharges (optional).
- Combination relief and inspection doors in head and tail sections.
- Cut-out "limit switch" available.
- Jig welded-assuring perfect alignment.

SPECIFICATIONS

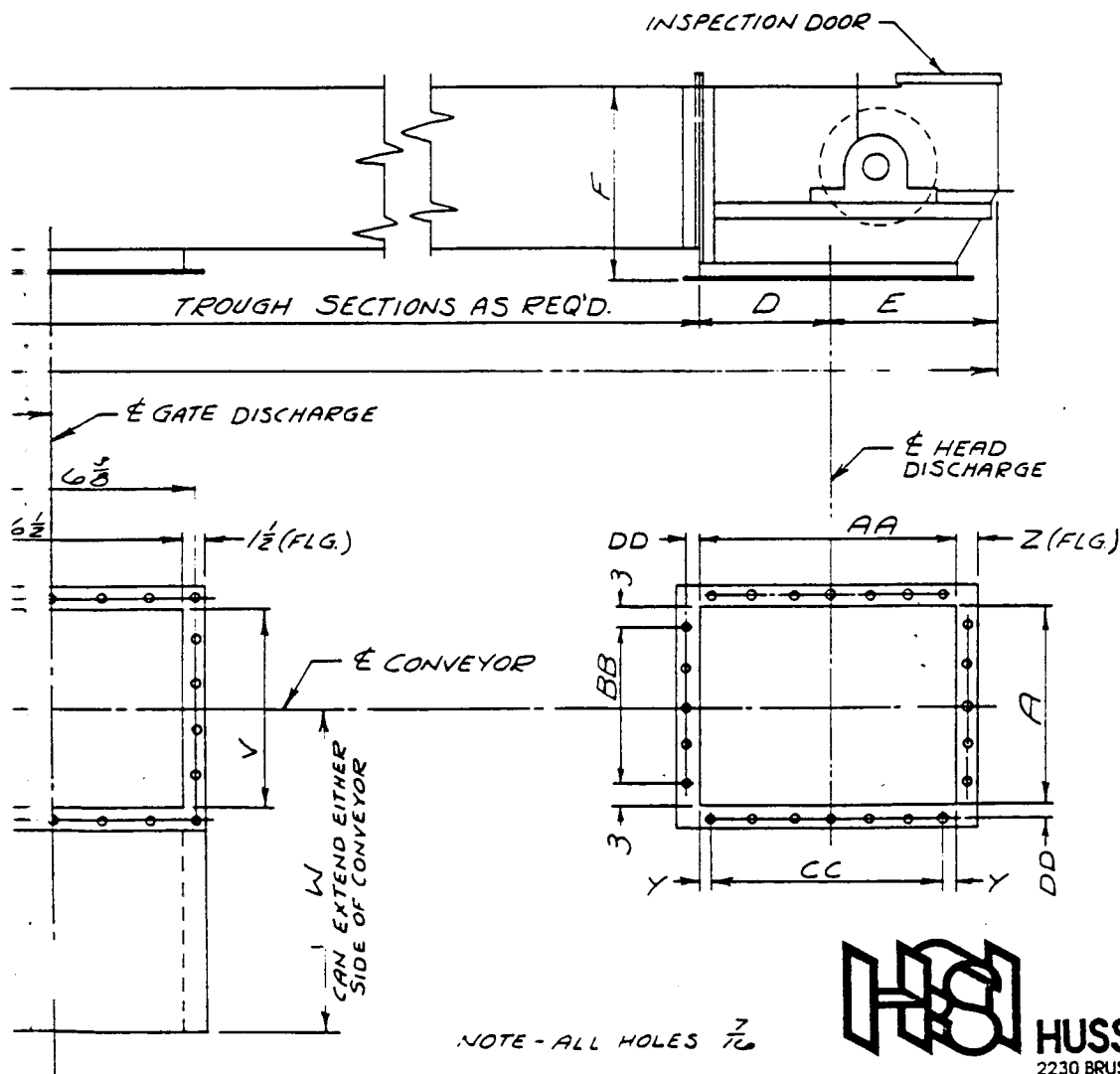
CONV. SIZE	A	B	C	D	E	F	G	H
12x22	12	22 ⁵ / ₈	41 ³ / ₈	15 ¹ / ₈	21 ¹ / ₈	26 ¹ / ₈	3	10 ¹ / ₂
18x22	18	22 ⁵ / ₈	41 ³ / ₈	15 ¹ / ₈	21 ¹ / ₈	26 ¹ / ₈	3	16 ¹ / ₂
24x22	24	22 ⁵ / ₈	41 ³ / ₈	15 ¹ / ₈	21 ¹ / ₈	26 ¹ / ₈	3	22 ¹ / ₂
30x22	30	22 ⁵ / ₈	41 ³ / ₈	15 ¹ / ₈	21 ¹ / ₈	26 ¹ / ₈	3	28 ¹ / ₂
18x28	18	28 ¹ / ₈	48 ⁵ / ₈	18 ¹ / ₈	24 ¹ / ₈	32 ⁵ / ₈	3 ¹ / ₂	16 ¹ / ₂
24x28	24	28 ¹ / ₈	48 ⁵ / ₈	18 ¹ / ₈	24 ¹ / ₈	32 ⁵ / ₈	3 ¹ / ₂	22 ¹ / ₂
30x28	30	28 ¹ / ₈	48 ⁵ / ₈	18 ¹ / ₈	24 ¹ / ₈	32 ⁵ / ₈	3 ¹ / ₂	28 ¹ / ₂
36x28	36	28 ¹ / ₈	48 ⁵ / ₈	18 ¹ / ₈	24 ¹ / ₈	32 ⁵ / ₈	3 ¹ / ₂	34 ¹ / ₂
42x28	42	28 ¹ / ₈	48 ⁵ / ₈	18 ¹ / ₈	24 ¹ / ₈	32 ⁵ / ₈	3 ¹ / ₂	40 ¹ / ₂
48x28	48	28 ¹ / ₈	48 ⁵ / ₈	18 ¹ / ₈	24 ¹ / ₈	32 ⁵ / ₈	3 ¹ / ₂	46 ¹ / ₂
54x28	54	28 ¹ / ₈	48 ⁵ / ₈	18 ¹ / ₈	24 ¹ / ₈	32 ⁵ / ₈	3 ¹ / ₂	54 ¹ / ₂



CROSS SECTION



K	L	M	N	P	R	S	T	V	W	Y	Z	AA	BB	CC	DD	EE	FF
—	23½	5¾	3@5½	15	1¾	5¾	1@5¼	14¼	27¾	1¼	1½	30	1@6	5@5½	1	24¼	15½
1@6	23½	5¾	3@5½	15	1¾	5½	2@5½	20¼	36¾	1¼	1½	30	2@6	5@5½	1	24¼	21½
2@6	23½	5¾	3@5½	15	1¾	5¾	3@5½	26¼	45¾	1¼	1½	30	3@6	5@5½	1	24¼	27½
3@6	23½	5¾	3@5½	15	1¾	5¾	4@5½	32¼	54¾	1¼	1½	30	4@6	5@5½	1	24¼	33½
1@6½	29½	5¾	4@5¾	19	2¼	5½	2@5½	20¼	36¾	1½	2½	36	2@6	6@5½	1¼	29¾	22½
2@6½	29½	5¾	4@5¾	19	2¼	5¾	3@5½	26¼	45¾	1½	2½	36	3@6	6@5½	1¼	29¾	28½
3@6½	29½	5¾	4@5¾	19	2¼	5¾	4@5½	32¼	54¾	1½	2½	36	4@6	6@5½	1¼	29¾	34½
4@6½	29½	5¾	4@5¾	19	2¼	5¾	5@5½	38¼	63¾	1½	2½	36	5@6	6@5½	1¼	29¾	40½
6@6½	29½	5¾	4@5¾	19	2¼	5¾	6@5½	44¼	72¾	1½	2½	36	6@6	6@5½	1¼	29¾	46½
8@6½	29½	5¾	4@5¾	19	2¼	5¾	7@5½	50¼	81¾	1½	2½	36	7@6	6@5½	1¼	29¾	52½
7@6½	29½	5¾	4@5¾	19	2¼	5½	8@5½	56¼	90¾	1½	2½	36	8@6	6@5½	1¼	29¾	58½



HUSS & SCHLIEPER
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